HYGIENE FOR STUDENTS

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BY

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PREFACE

The present issue, though under a different title, is in fact a fourth edition, greatly enlarged and improved, of the *Principles of Hygiene*, which, originally published by Messrs. Collins in 1884, and again in 1888, in their series of "Advanced Science Text Books," was taken over by Messrs. Macmillan in 1893. Having been designed from the first expressly as a manual for the examinations of the Science and Art Department, it has followed the syllabuses for the Elementary and Advanced Stages, save that, except in the first edition, the immediate treatment of wounds, accidents, "fits," &c., though required by the syllabus, has been omitted as irrelevant. To the subjects, a knowledge of which is indispensable in the case of candidates for Honours, as well as for the Inspectors' Certificates at the Sanitary Institute, Diplomas in Public Health, &c., I have given more or less consideration, as I thought would conduce to the *general* usefulness of the work. Thus I have ignored Sanitary Law altogether,

believing that, without nearly doubling the size of the volume, it could not be treated to any good purpose. As regards Unhealthy Trades I have restricted myself to a general statement and classification of the conditions inimical to health incident to each class of industries, and the principles on which all preventive or remedial measures must be based. Under the head of Sewage Disposal I have withdrawn all description of the Chemical methods of treatment, mentioning them merely to condemn them without exception; while, on the other hand, I have explained as fully as space permitted the theory and working of the Bacterial Tanks and Filters, which I maintain should be adopted wherever Irrigation cannot be advantageously carried out.

Demography, or Vital Statistics, will be found to be treated with greater fulness than in any work not solely devoted to the subject, especially in the elucidation of the paradoxes and exposure of the fallacies incident thereto, and from one or other of which very few reports or discussions are wholly free; those connected with the age and sex-constitution of populations or classes of persons being perhaps the most insidious and inveterate.

In the chapter on Dietetics I have from the first adopted the conclusions of Pettenkofer, Erwin Voigt, and others of the Munich School, which, as the outcome of exact experimental methods, placed the doctrine of the functions and metabolism of the several food stuffs on a sound scientific basis; but in this edition

I have added the striking results of the recent researches of Salkowski, Horbaczewski, Eng. Taylor, &c., into the sources and genesis of urea and uric acid respectively, which have had the effect of exploding a large mass of medical tradition.

I have entirely rewritten the sections on the chemical analysis of milk, butter, and potable waters, substituting the latest and most improved methods, and have added a discussion of the value to be attached to each form of impurity under different conditions of source and collection, as well as of the information afforded by a bacteriological examination.

The success that has attended the employment of antitoxine in diphtheria, and to a less extent in some other diseases, with the light thrown thereby on the nature of immunity; and the brilliant discoveries of Manson, Ross, Grassi and other observers on the life cycle of the blood parasites of filariasis, so-called malarial and yellow fevers, have necessitated an entire recasting of the chapter on Infectious Diseases.

The tabular arrangement of specific diseases on pp. 370, 371, which first appeared in my pamphlet on the *Natural History of Specific Diseases*, published in 1889, and has been revised from time to time as required by the growth of our knowledge, remains still, I believe, the only serious attempt at a rational and scientific classification. Some of my statements, especially as to cholera, diphtheria, and the influence of small-pox hospitals, may appear somewhat dogmatic, and opposed to traditional teaching, but I am

prepared to defend them, and I have the support of many of the most judicious and independent authorities.

In the section on School Hygiene I have adopted the views on lighting of Professors Cohn and Förster, of Breslau, the highest living authorities on the eye; to the latter of whom I am indebted for the diagrams illustrative of the relation between the incidence and the intensity of the light, though the conclusions as to the best positions and aspects of windows, &c., are my own; and for the physiology and psychology of the education of girls I alone am responsible.

I have added to each chapter a summary of its contents and a number of examination questions, partly selected from the papers given at South Kensington during the last eight years, and partly original, the latter being specially designed to elicit a thoughtful interest in the subject, rather than to serve as mere exercises of the memory.

I have endeavoured throughout so to combine scientific accuracy with the popular treatment of the subject, as to render the work a clear and comprehensive Manual of the Principles and Practice of Public Health, equally adapted to the purposes of the medical man, the student, the teacher, and the general reader.

Those who want a technical and detailed treatment of practical sanitation, &c., and a *précis* or digest of Sanitary Law, will find them in my *Health Officers' Pocket Book*, the two books, while partly

covering the same ground, being, to a great extent, complementary to one another.

I cannot conclude without expressing my obligation to Messrs. Macmillan for the pains they have taken, regardless of trouble or expense, in the preparation of this edition, and especially to Prof. R. A. Gregory for his unvarying courtesy and kind advice and suggestions, which I have found of the greatest value; as well as to Dr. Kenwood, Dr. Barwise and Mr. Pakes, in the practical treatment of Water Analysis and bacteriological examination.

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CONTENTS

PART I

HEALTH OF THE MAN

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IV

CHAPTER V

CHAPTER VI

PART II

HEALTH OF THE HOUSE

CHAPTER VII

CHAPTER VIII

CHAPTER IX

CHAPTER X

PART III

HEALTH OF THE CITY

CHAPTER XI

CHAPTER XII

CHAPTER XIII

CHAPTER XIV

PART IV

HEALTH OF THE PEOPLE

CHAPTER XV

CHAPTER XVI

CHAPTER XVII

CHAPTER XVIII

PART V

DEMOGRAPHY

CHAPTER XIX

PART VI

METEOROLOGY

CHAPTER XX

APPENDIX

LIST OF ILLUSTRATIONS

ERRATA.

Page 406, line 26, *for* or *read* as.
Page 459, lines 5 and 11, *for* carbonic acid *read* carbon dioxide.
Page 524, line 7 from bottom, *for* syphon *read* siphon.

HYGIENE FOR STUDENTS

PART I

HEALTH OF THE MAN

CHAPTER I

THE FOOD STUFFS, ETC.

ALL plants and animals, when reduced to their constituent elements, are found to consist of carbon, hydrogen, nitrogen, and oxygen, with a variable proportion of iron, earthy and alkaline salts, viz., phosphates, chlorides, sulphates, carbonates, etc., of potassium, sodium, calcium, magnesium, &c. But they differ from the objects of the inanimate world, not only in manifesting those phenomena which collectively indicate the state we call life, and in possessing in a greater or less degree that peculiar structure known as organisation, on which account they are spoken of as organisms, but also in the fact that their carbon, hydrogen, oxygen, and nitrogen are for the most part combined in the form of highly complex bodies peculiar to the animal and vegetable worlds, and described as the proximate constituents of organisms. These bodies are divided into three well-marked groups—the albuminates, fats, and carbohydrates, the first two of which are most abundant in animal

and the last in vegetable tissues, though all three are represented in each. The albuminates alone contain nitrogen, whence they are often spoken of as the nitrogenous constituents, and the others as the non-nitrogenous. The carbohydrates, again, differ from the fats in the fact, which is implied in their name, that their oxygen and hydrogen are present in the same proportion as in water; not that they exist in the form of water, but that there are always two atoms of hydrogen to one of oxygen, or in other words, eight parts by weight of oxygen to one of hydrogen.

Physiologically and chemically albumin must be considered as the most highly differentiated body; it is most intimately associated with the exercise of function; it is the essential constituent of that substance, protoplasm, which has been described as the physical basis of life, being that in and by which alone all the activities and phenomena of life are manifested, and to which all structure and nutritive processes are subservient; and its highly complex character distinguishes it further from the non-nitrogenous constituents.

The formulæ representing the composition of the fats and carbohydrates are more simple, and these bodies present greater analogies to those of the inorganic and inanimate world, being intimately correlated with the alcohols, acids, ethers, &c., and some of them capable of being formed *de novo* from these, or even by synthesis from their ultimate elements. Again, while, with the exception of cellulose, they exhibit no trace of organisation, fats and sugars often assume the crystalline form so general among inorganic bodies.

Albuminates or Proteids

The general percentage composition is:

Oxygen . . .	21 to 23·5%	Carbon . .	51·5 to 54·5%
Hydrogen . .	7%	Sulphur . .	3 to 2·0%
Nitrogen . .	15 to 17%	Ash, variable.	

All are amorphous when withdrawn from the tissues, *i.e.*, they are never crystalline; some are soluble, others insoluble in water; and all are nearly insoluble in alcohol and ether. They are soluble in acids and alkalies, but undergo changes in being dissolved.

Albumin exists in numerous forms differing slightly in their physical properties and their reactions. But it will be sufficient for our present purpose to mention those only which enter largely into the composition of our food, or play an important part in the digestive process. These may be conveniently arranged as follows:

I. *Animal Albumins*—

1. Egg albumin. } or soluble albumins.
2. Serum albumin. }
3. Myosin. 4. Nuclein Albumins.
5. Casein. 6. Fibrin. 7. Globulin.

II. *Vegetable Albumins*—

1. Vegetable albumin.
2. Glutin.
3. Legumin (or vegetable casein).

III. *Secondary Albumins*—

1. Acid albumin (Syntonin).
2. Alkali albumin (artificial casein).
3. Peptones.

IV. *Gelatinoids*—

1. Chondrin. 2. Gelatin.
3. Mucin.

Egg albumin constitutes nearly the whole of the solids in the white of eggs and one-third of those in the yolk of the egg (the rest being composed of fat). **Serum albumin** is the principal solid constituent of blood serum, and as such exists in flesh. It is present also in milk along with another albumin, viz., casein. Egg and serum albumins are soluble in water, precipi-

tated by strong alcohol, which after long contact renders them insoluble; and are coagulated by heat. Other reactions and properties are of no importance in dietetics.

Myosin constitutes the bulk of dead muscle; is soluble in weak saline solutions, as of sodium chloride, from which it is thrown down by adding excess of salt or water; is readily coagulated by heat; and otherwise behaves like the above-mentioned albumins. It is obtained from muscle by first washing out the serum, &c., dissolving the mass so far as possible in a 10 per cent. solution of common salt, and dropping the viscid fluid into a vessel of distilled water, in which it forms a flocculent deposit.

Casein is the chief nitrogenous solid of cows' and goats' milk, which contains also a small proportion of serum albumin, from which the casein differs in not being coagulated by heat. It is readily soluble in dilute acids and alkalies, whence it is reprecipitated by neutralisation. In the presence, however, of potassium phosphate, as in milk, a stronger acid is required for its precipitation than otherwise. It is also coagulated by rennet (pepsin and acid). It is best obtained from milk by diluting the milk with several times its volume of water, adding dilute acetic acid till a precipitate begins to form, passing carbonic acid through it, filtering and washing the precipitate with alcohol and ether.

The nitrogenous constituents of plants have been less carefully examined than those of animals, but it may be broadly stated that vegetable albumin, which is present in small quantities in most plants, corresponds very closely with animal albumin, and like those of egg and serum is coagulable by heat. It is thus obtained from the juices of plants.

Legumin resembles casein, and, like it, is coagulated by acetic acid or rennet but not by heat. It is found chiefly in the seeds of the Leguminosæ (peas, beans, lentils, &c.).

Glutin occurs largely in the seeds of cereals (rice containing the least) ; is broken up by treatment with alcohol into vegetable fibrin and gliadin, a body analogous to gelatin.

Vegetable albumins contain a somewhat larger percentage of nitrogen than do the animal, but this is of no practical importance.

Syntonin. Any albumin, when subjected to the prolonged action of dilute hydrochloric acid is converted into acid albumin, and when similarly treated with dilute potash or soda solutions into alkali albumin. Neither of these derived albumins is soluble in water or in neutral saline solutions, and thus neutralisation of either solution causes a precipitate soluble in the former case by alkalies, and in the latter by acids. Neither acid nor alkali albumin is coagulated by heat alone. A very weak (0·2 per cent.) solution of hydrochloric acid will dissolve and convert into acid albumin a great part of finely-chopped muscle from which the serum has been washed out, *i.e.*, will dissolve and convert myosin into this form.

Casein, though not identical with, is allied to alkali albumin, and owes its power of remaining uncoagulated by a slight degree of acidity to the presence of potassium phosphate.

Peptones.—Any form of albumin exposed to the action of acid gastric or alkaline pancreatic juice, is converted into a peptone, the change being effected in the one case by pepsin and hydrochloric acid, in the latter by trypsin and the alkaline salts of the bile. Peptones are not precipitated by boiling or by acids or alkalies, and with difficulty by alcohol, the few reagents which do precipitate them, with the exception of bile acids in an acid solution, falling outside the field of dietetics. But by far their most important character is their extreme diffusibility, for whereas the other albumins even when perfectly dissolved are incapable of passing through an animal membrane, the peptones do so with such rapidity that, though

formed in abundance in the process of digestion, they are found only in very small quantities in the contents of the alimentary canal. They are absorbed as fast as made, and reconverted after absorption into the other forms in which they occur in the tissues. Neither pepsin nor trypsin is essential to their production, since acids and moderate heat, or even long boiling in pure water under high pressure, are capable of affecting the transformation to a greater or less extent.

Gelatin and its allies, chondrin, mucin, &c., are obtained from connective tissue, cartilage, &c., by prolonged boiling, which change may be greatly aided by acids, or by being performed under pressure. They resemble the albumins in their composition, but are acted on by fewer reagents. They are probably not present as such in the tissues, and are formed only by the treatment employed for their extraction. They are easily soluble in warm water, and in the process of digestion—peptic or tryptic—yield for the most part like products with the albuminates, though, there is reason to believe, they are not available for the repair of the tissues.

There is one remarkable body, a *nitrogenous fat*, Lecithin, containing phosphorus, a constituent of brain, and present also in the yolk of the egg.

THE NEUTRAL FATS

These may be regarded as glycerides or ethers formed from the triatomic alcohol glycerine $\left.\begin{matrix} C^3H^5 \\ H^3 \end{matrix}\right\} O^3$ or $C^3H^5\,(HO)^3$ and the higher terms of the acetic or the oleic series of acids

The fats do not contain glycerine, though glycerine is obtained from them. They stand in the same relation to it as the so-called compound ethers do to ethylic alcohol.

They are neutral bodies, colourless and tasteless when pure, insoluble in water and cold alcohol, soluble in hot

alcohol, ether, chloroform, benzol, carbonic sulphide, &c., and in one another, and are decomposed by alkalies into glycerine and soaps, or by superheated steam into glycerine and their respective fatty acids.

Three only are of importance in connection with our subject, viz. :—

1. Olein, } Common to the animal and vegetable kingdoms.
2. Palmitin, }
3. Stearin, Peculiar to the animal.

Their chemical composition may be represented according to the theory we accept of their relation to glycerine as follows :—

$$\text{Olein, } \left.\begin{matrix} C_3H_5 \\ (C_{18}H_{33}O)_3 \end{matrix}\right\} O_3 \text{ or } C_3H_5\ (C_{18}H_{33}O_2)_3.$$

$$\text{Palmitin, } \left.\begin{matrix} C_3H_5 \\ (C_{16}H_{31}O)_3 \end{matrix}\right\} O_3 \text{ or } C_3H_5\ (C_{16}H_{31}O_2)_3.$$

$$\text{Stearin, } \left.\begin{matrix} C_3H_5 \\ (C_{18}H_{35}O)_3 \end{matrix}\right\} O_3 \text{ or } C_3H_5\ (C_{18}H_{35}O_2)_3.$$

At the ordinary temperature of the air olein is fluid, the others are solid, and when pure, take in cooling a crystalline form, palmitin as needles, stearin as square tables ; the melting point of neither is fixed, but palmitin is always solid below 45° C. (103° F.). Stearin is the hardest and least fusible. To the proportion in which olein, palmitin and stearin enter into their composition, the different fats of mutton, beef, pork, suet, lard, and butter owe their relative hardness or softness and mean melting points. Butter contains also lower fatty acids, butyric, &c., which are volatilised at the temperature of boiling water.

Carbohydrates

comprise the numerous forms of sugar, starch, and gum, including also woody fibre. They owe their name to the fact that besides carbon they contain hydrogen and oxygen in the same proportions as these exist in water.

They are for the most part vegetable products, though lactose exists abundantly in milk and glycogen is formed in liver. They may be divided into three groups, having the respective formulæ affixed, together with in some cases one or two molecules of water of crystallisation.

(1) *The Glucoses* —$C_6H_{12}O_6$. (2) *The Sucroses*—$C_{12}H_{22}O_{11}$. (3) *The Amyloses*—$C_6H_{10}O_5$.

Starch + Water = Glucose.

Starch + Glucose, or 2 Starch + Water, = Sucrose.

Glucose or **Grape Sugar**, also called dextrose, from its power of rotating the polarised ray to the right, is present, ready formed, in grapes and other fruits, and in honey along with the isomeric form of levulose or fruit sugar, so called from its left-handed rotation of the polarised ray. Dextrose is crystalline, levulose is not, but forms a colourless syrup. Dextrose exists in small quantities in blood and in the egg, and is the sugar of diabetic urine. Dextrose is formed by the action of the diastase of malt on starch, and by boiling starch with dilute acids : sucrose also is broken up into dextrose and levulose by dilute acids. Dextrose is soluble in water and dilute alcohol, and is directly fermentable *i.e.*, broken up by the action of yeast, or allied organisms, into alcohol and carbonic acid, $C_6H_{12}O_6=2\ (C_2H_6O)+2\ CO_2$.

When either sucrose, lactose, or amylose is fermented it is first converted into glucose.

Sucrose or **Cane Sugar** exists abundantly in the juice of the sugar cane and sugar maple, and in smaller quantities in fruits along with the two forms of glucose, while a very similar sugar, Betose, is obtained from the beetroot. It is crystalline, but in the process of manufacture a large proportion is transformed into levulose of an impure kind, dark from the presence of caramel or burned sugar, and known as molasses or treacle. Much of this is utilised for the production of rum.

Sucrose is soluble in water, but nearly insoluble in alcohol ; it is much sweeter than glucose.

Maltose, the final product of the action of the diastase on starch, belongs to this group. **Lactose,** or sugar of milk, is less soluble in water, and less sweet than any of the foregoing. It is not directly fermentable, but becomes so after conversion by dilute acid into galactose. In the presence of decomposing albumin, &c., it is rapidly transformed into lactic acid.

The **Amyloses** include starch, gum, dextrin, &c. woody fibre or cellulin and pectose or vegetable jelly.

Starch is a highly important article of food present in most seeds, roots, &c., especially abundant in the seeds of the cereals and leguminosæ, in the tubers of the potato, the stem of the sago palm, &c. Starch exists in these in the form of granules, or bodies having a distinctly organised structure, and consisting of an envelope of insoluble cellulin, variously wrinkled and marked, and more soluble contents known as granulose. These granules vary in size and form with their source, and may thus be distinguished under the microscope. Starch, when boiled, combines with iodine, producing a deep and intense blue colour, by which its presence may be detected. In the cold a longer time is required for the reaction ; the colour disappears on boiling, but reappears when the solution cools. Starch is insoluble in cold water or alcohol, but above 70° C. water causes the granules to swell out and burst. Long boiling with much water, converts a portion of the contents into a soluble form, from which the insoluble one separates on cooling.

Heating at 160° C. converts starch into **dextrin.** The change is greatly aided by the presence of a small quantity of dilute mineral acid. The treatment, if prolonged, converts it into dextrose. Diastase turns it into dextrose and maltose. This is the intermediate stage in the production of alcohol from starch, as in brewing, and in the manufacture of spirits.

Cellulose, or woody fibre, forms the framework of

plants. Its dietetic value is only that of an intestinal stimulant, since it is insoluble, and in its matured condition refractory to all reagents, except strong acids and caustic alkalies.

Pectose, or vegetable jelly, is found in many ripe fruits, having been present in the unripe stage as an insoluble body **pectin.** Little is known of its composition or properties ; the same may be said of other unfermentable carbohydrates, as inosite, &c.

The vegetable acids, tartaric, citric, malic, and oxalic, though not strictly speaking foods, have doubtless, like the alkaline salts, a dietetic value, of which the best evidence is afforded by the efficacy of lime juice or fresh fruits in the prevention and cure of scurvy.

This is perhaps the fittest place for a few remarks on the causation of scurvy, which, though favoured by hardship and privation generally, is essentially a dietetic disease, and perfectly preventable. Formerly it was no uncommon event for a man-of-war to return from a long voyage with the entire crew more or less incapacitated or having lost half her hands ; now it is unknown in navies or well-appointed lines, even the shipwrecked crews of the *Polaris* and the *Eira* in the Arctic regions having escaped. Deprivation or great deficiency of fresh vegetables, unless compensated by certain substitutes, sooner or later induces it, and its development is favoured by the exclusive use of salt meat ; but it is hard to say what are the essential salts or other bodies on whose presence or absence the prevention or induction of the disease depends. Certain it is, that so long as men enjoy a due proportion of fresh vegetables of any kind, or of potatoes, they escape ; and that the most liberal diet from which these or the potash salts of the vegetable acids are absent does not suffice to avert it. The best preventives, or remedies if it have appeared, are the citrates, tartrates, or malates of potash, or fruits, fresh or dried, containing these ; next, lactates, oxalates, and acetates of the same, though in an inferior degree ; fresh vegetables of any kind, potatoes, and, though feebler, dried vegetables ; while fresh or raw meat and blood have been found to avert, if not to prevent, its development. Lime juice alone, a mixture of citric acid and citrate of potash, is a preventive and a specific, though the diet may be defective in every other respect. From

these facts it has been generally assumed that the potash salts of the organic acids (citric, tartaric, &c. in fruits and vegetables, and lactic in meat) were the essential factors, for the acids alone have little virtue, and the carbonates into which the above-mentioned salts are transformed in the blood have none. But the value of potatoes admits of no dispute, yet their acidity is trifling. The crew of the *Polaris* subsisted for many months on pemmican alone, but it was of the sweet kind containing raisins. Dr. Neal, of the *Eira*, attributed the immunity enjoyed by her men to their having at his suggestion drunk the fresh blood of the animals they killed, but they had also a daily ration, though a small one, of dried vegetables. The acids and their salts in fruits enter the circulation as such, but are soon converted into alkaline carbonates. Scurvy, usually associated with rickets, sometimes appears in artificially fed infants, through their inability to assimilate a diet in itself sufficient for others. Such cases must be treated by a special diet of oil, oranges, potatoes and raw meat as well as milk and cream.

The question, from a theoretical point of view, is obscure, but happily in practice no real difficulty is felt, as our empirical knowledge is amply sufficient to banish this disease for ever.

Classification of Foods

The popular division of foods into animal and vegetable is neither scientific nor satisfactory; not that it is a matter of indifference whether a man subsists on a purely animal or an exclusively vegetable diet, or on one derived from both kingdoms, but the differences depend not on the source whence the foods are obtained, but on the proportions in which the several food-stuffs—albuminates, fats, and carbohydrates are combined, and on the digestibility and other special properties of the particular forms in which the representative members of these classes occur in the diet in question.

Since the albuminates are common to both, the essential difference between animal and vegetable foods, viz., the absence of carbohydrates, milk and sugar excepted, from the one, and the very small proportion of fat in the other, is lost in the free inclusion of milk, butter, and eggs (!) in so-called *vegetarian* dietaries.

Uses of Food

The purposes served by food are—

1. The repair and restoration of the tissues.
2. The evolution of energy, in the forms of
   (*a*) the production of animal heat.
   (*b*) the exercise of function.

In other words, the materials supplied in the form of food, and digested and absorbed by the organism, are partly employed for building up growing organs, and making good the wear and tear, the loss of substance, which they are constantly undergoing; and partly as fuel for the production of heat, and of energy manifested as functional activity, internal or external.

These facts have been, if not explicitly expressed, consciously or unconsciously known by mankind in all ages, and are demonstrated by the loss of flesh, the inability to resist external cold, &c., or to undergo any great bodily or mental exertion which follows deprivation or extreme restriction of food. But it was Liebig who put forward the first rational theory of nutrition. In his researches on the food of plants, the influence of which for good on the entire practice of agriculture surpasses calculation, he showed that we could learn from the composition of the vegetable ash what minerals entered into the constitution of the plant, and by providing them in the right proportions, enable almost any soil to carry any crop. From plants he reasoned to animals, forgetting that plants evolve little heat, and do no work. He knew that plants built up their structures out of inorganic materials,—carbon dioxide, derived from the air, and ammonia and nitrates being to them what the non-nitrogenous and nitrogenous food-stuffs respectively are to the animal, who obtains from the air merely oxygen for the support of oxidation processes within, and must receive all food properly so-called in the complex organic forms of albumin, fat, and carbohydrate. He knew that as every true

tissue and every organ was largely composed of nitrogen, it was physically impossible that these could be repaired, restored, or built up from non-nitrogenous matters only, in other words that nitrogenous food-stuffs were essential to tissue formation; whereas non-nitrogenous matters, though by themselves useless for this purpose, might be at least as available for the production of heat. The physiologists of the day, recognising in the metabolism of the tissues the only source of functional activity, concluded that each organ in the exercise of function consumed a certain proportion of its own substance. If the organism might be compared to a steam-engine, it must, said they, be one which did not merely suffer wear and tear, but worked at the expense of its own material instead of fuel. Liebig consequently assumed that albuminous nourishment, which he distinguished as flesh-forming food, must be supplied in direct ratio to the amount of muscular activity demanded, while the fats and carbohydrates he considered to be fuel for the production of heat only, and he therefore called them respiratory foods.

According to this theory, the elimination of urea and uric acid, which together represent the whole of the nitrogenous materials metabolised in the organism, should be proportioned to the amount of energy put forth, but such is certainly not the case. For a short time the difficulty was met by the theory of *luxus consumption*, which assumed that when more albumin was ingested than was required for the repair of the tissues, the excess underwent combustion in the blood with evolution of heat, thus playing the part assigned to the carbohydrates and fats. The measure of the necessary albumin was supposed to be afforded by the excretion of urea observed during abstinence from all nitrogenous food.

Moleschott raised the first protest against the speculations of the famous chemist, but it was Voit who demolished the whole theory by showing that no such im-

mediate relation exists, for while the amount of albumin metabolised by a fasting animal is insufficient, even when combined with the due proportion of carbohydrates and fats, for the maintenance of life, very severe muscular exercise does not, unless prolonged, appreciably increase the elimination of urea, though it does that of carbonic acid enormously. Pettenkofer and Voit kept a man for several days in the experimental chamber at the Munich Laboratory, where they could accurately estimate the oxygen taken in, and the carbon dioxide and water given out from the body. On some days he was employed for several hours in manual labour, viz., turning a heavy wheel, though not beyond his strength, and on others he enjoyed entire rest. The following table shows the results obtained :—

	Absorption of Oxygen in Grammes.	Elimination in Grammes.		
		Carbon dioxide.	Water.	Urea.
Rest Day . . .	708·9	911·5	828·0	37·2
Work Day . . .	954·5	1284·2	2042·1	37·0
Excess on work day (with exception of urea)	246·6	372·7	1214·1	−0·2

Voit's farther experiments clearly point to the conclusion, that the greater part of the albumin taken in the food is accumulated *pro tempore* in the general fluids of the body, whence so much is withdrawn by the tissues as is required for their repair, and that this fluid albumin is much more easily metabolised than that which has already entered into the structures. In a previously well-fed dog the daily excretion of urea during the first few days of fasting was no less than sixty grams, but when the stock of free albumin was exhausted it sank to ten or

twelve ; while in one that had not previously had more than was barely sufficient for the maintenance of the *status quo*, the excretion from the first never exceeded fourteen, since the organised albumin of the tissues, metabolised with more difficulty, had to be drawn on from the commencement of the period of starvation.

In health a certain excess of albuminous food above the actual necessities of the tissues—in other words, an ample stock of albumin dissolved in the juices of the body—appears requisite for great functional activity, and to afford the power of resistance to injurious influences, as exposure to the elements or disease ; but if the ingestion of albumin be continued in greater excess, the surplus is immediately subjected to metabolism ; the excretion of urea depending on the amount of albumin ingested, and not on the muscular activity, as Liebig taught. Albuminous metabolism on a subsistence diet, or when the bodily equilibrium is exactly maintained, is nearly a constant quantity, and is almost the same whether an animal be fed on a scanty and purely nitrogenous diet, or is actually starving. The quantity of albumin required to maintain healthy functional exercise and bodily equilibrium is the same for the same individual, whether idle or at work ; for the waste and repair of the tissues is subject to far less variation than was formerly imagined, and to make good the constant waste is its sole use. Additional work demands an increase of fats and carbohydrates, which are the real sources of energy no less than of heat. It is perfectly true that a navvy or a smith requires more albumin, that is, practically more meat, than a draper or a watchmaker ; but this is simply because he has, as a rule, a larger frame and more highly developed muscles to maintain ; neither will be rendered capable of greater exertion by suddenly increasing his allowance of albumin, supposing it to have been previously sufficient to preserve his equilibrium. Only when a man has been reduced by illness, or when a feeble man

is, by judicious training, developing a larger muscular frame, will an increase of albuminous food give him greater strength ; but then the increase must be gradual, and conducted *pari passu* with the increase of bulk in his muscles.

Potential Energy contained in Food

Here again the speculations of chemists have been proved to be erroneous by the carefully conducted experiments of physiologists, especially Pettenkofer and Voit. The discovery of Joule that the amount of mechanical power obtainable from a given weight of fuel was directly proportional to, because connected with, the heat given out in its combustion, which is transformed into mechanical power, though with some inevitable loss from radiation, conduction, and friction, was eagerly seized on by Professors Frankland and Playfair, who fancied that they could thus estimate the energy contained in different kinds of food. This would be possible if metabolism in the body were identical with combustion out of it, and if the former process were complete ; but neither is the fact The impulse to metabolism seems to proceed from the cells themselves, and to be more of a vital than of a chemical nature, the oxygen combining rather with the products of the splitting-up of the food-stuff than directly and primarily with the latter, and it is certain that there is little or no relation between the facility with which any given substance combines with oxygen (*i.e.*, burns) in the air, and under the totally different conditions under which it finds itself in the animal body. Thus fats are undoubtedly less easily metabolised than the carbohydrates, notwithstanding the ease with which they are burned, and albuminates are far more so than their low combustibility would lead one to expect. Albumin splits up into products, one of which is fat, and the others, immediately or remotely, carbon dioxide and water, urea and uric acid.

It is, therefore, probably the true source of the fat stored up in the body ; and the apparent fat-producing power of the carbohydrates is owing to their easy metabolism, saving the albumin which would otherwise have been employed in the production of heat and force. There is absolutely no evidence of the conversion of carbohydrates into fat, although it is conceivable that under certain circumstances the fats may be stored up unchanged.

An excessive amount of albumin relatively to the non-nitro-

genous food-stuffs tends to loss of weight by the stimulus it gives to metabolism. Experiment on the living animal shows this very clearly. For instance, a dog which on a daily diet of 500 grams of pure flesh and 500 of fat gained weight for a month, began to lose weight after the allowance of flesh was increased to 1500 grams without a corresponding increase of the non-nitrogenous food.

Again, Frankland's estimates of the energy contained in equal weights of each article of food based on the heat given off in their combustion, are not confirmed by experiment or by common experience. Since, however, his views are still accepted by some authorities, and questions on them may be given in examination papers, we will subjoin a few of his figures.

He calculates that—

One	ounce	of dry albumin	yields	174	foot-tons	of potential	energy.
,,	,,	fat	,,	378	,,	,,	,,
,,	,,	starch	,,	135	,,	,,	,,
,,	,,	cane sugar	,,	129	,,	,,	,,
,,	,,	glucose or lactose		122	,,	,,	,,

While the chemists consider 240 parts of starch to be required to produce the same amount of energy as 100 of fat, Pettenkofer and Voit infer from their experiments that 175 of starch are equivalent to 100 of fat in the animal body. For it is not the ease with which a substance is burned, but with which it is digested and utilised, and the processes of splitting up and of combination it undergoes in the organism, that determine its real value.

Products of Nitrogenous Metabolism

The time-honoured doctrines that urea was the ultimate product of all nitrogenous metabolism, and uric acid a transitional stage in the process, or evidence of its incomplete performance, and that its accumulation or retention in the blood was the cause of the phenomena of gout, &c., are no longer tenable. Though uric acid can be oxidised into urea, they are, under normal conditions, of different origins, some albumins yielding urea only, and others, known as nucleins, being the sole source of uric acid. Uric acid, too, is non-toxic, and may be injected into the

circulation daily for long periods with no effect; but all the phenomena of gout, of the so-called "uric-acid diathesis," and of uræmia are produced by the presence of a greater or lesser excess of xanthin, hypo- and para-xanthin, and known as alloxuric bases, products of excessive and imperfect nuclein metabolism, which freer oxidation would have converted into uric acid.

Among foods, pulse (legumin) and the yolk of eggs, as the richest in nucleins, are the greatest producers of uric acid, while meat extracts, thein and caffein, consisting mainly of, or being closely allied to the alloxuric bases, are excreted entirely as uric acid, and were therefore supposed to check nitrogenous metabolism. But if the diet be otherwise unchanged, the increase in the uric acid will be found to correspond with the consumption of tea or coffee, and to be unattended by any decrease in the urea, which the old doctrine would require. The white blood-cells contain nuclein only, and any conditions involving excessive production or destruction of leucocytes is also followed by increased formation of uric acid.

Quantity of Each of the Food Stuffs Required

We have seen that the nitrogen of the food is not properly a source of energy, but is devoted to the maintenance of the organism itself. If, as in early life, the body is growing in weight and stature, or as in convalescence after wasting diseases as typhoid fever, &c., the loss of substance has to be made good; or lastly, when by a judicious course of diet and gymnastic or other exercise, a frame comparatively feeble but still capable of increase in bulk of muscle and vigour is being gradually developed and improved, an excess of nitrogen over that required to preserve the *status quo* will be actually assimilated; but with a healthy adult under ordinary circumstances, his physiological establishment, so to say, is fixed, and under perfectly normal conditions he neither gains nor loses weight, but preserves what is called his bodily equilibrium. If his diet be accurately adjusted to the perman-

ent requirements of his bodily frame and the amount of work which he is performing for the time being, the carbon, hydrogen, nitrogen, and oxygen taken in by the stomach and lungs will be exactly balanced by that given off by the kidneys, bowels. skin, and lungs, or, as it is expressed, the intake and output will equal one another.

It is therefore evident that inasmuch as no two persons are precisely alike in physique and activity, no hard and fast line can be drawn for all, but an approximate estimate can be made by calculating the diets of healthy men, who, with perfectly unfettered choice, are found to maintain their equilibrium. Many such calculations have been made for average men, which show as close an agreement as could reasonably be expected, and the correctness of these estimates is indirectly confirmed by the observation of other individuals of abnormal physique or working under unusual conditions. Thus in round numbers the quantity of dry food necessary in rest is albumin 3 oz., fat 1½ oz., carbohydrates 12 oz.; in ordinary work—albumin 5 oz., fat 3 oz., carbohydrates 15 oz.; while in very laborious work, albuminates 6 to 7 oz., fats 3·5 to 4·5 oz., and carbohydrates 16 to 18 oz., the salts rising also to 1·2 to 1·5 oz. (Parkes).

J. Forster found that the diet of several strong healthy men having entire freedom of choice had the following composition in grams:

	Alb.	Fat.	Carbohydrates.	N.	C.
Porter, 36 years of age	133	95	422	21	320
Carpenter	131	68	494	20	342
Young medical man, A	127	89	362	20	297
" " B	134	102	292	21	280
Powerful old man	116	68	345	18	220

The correspondence between the amount of carbon and the muscular exertion required in their respective callings is noteworthy, as well as the trifling difference in the albumin, except in the case of the old man in whom

tissue changes would naturally be slowly performed. The preference shown by some for the one and by others for the other class of non-nitrogenous foods is interesting.

Professor Beneke found that he could preserve his own equilibrium on 94 grams of albumin, 109 of fat, and 284 of carbohydrates, although he weighed 62 kgs. = 137 lbs.; but then his employment did not demand much *muscular* exertion. Students and labourers work under totally different conditions, and an investigation of the influence of mental strain on metabolism is much to be desired. When a person is not engaged in any muscular work the maintenance of heat and the integrity of the tissues have, of course, to be provided for, but the work of the heart and muscles of respiration is the only mechanical effort. Thus, aged persons passing their time in well warmed rooms require very small amounts of food. J. Forster found that the old ladies in an asylum for clergymen's widows did not consume on an average more than 80 grams of albumin, 49 of fat, and 266 of carbohydrates, while some of the most aged and sparest were satisfied with 67 of albumin and 38 of fat.

Pettenkofer and Voit carried out a series of observations unparalleled for precision, analysing and estimating the entire intake and output as represented by food, excreta and air respired. They found that a strong man weighing 69·5 kgs. = 153 lbs., and taking a fair quantity of mixed food, whether at rest or at work, metabolised just 137 grams of albumin, the intake and output of nitrogen under either circumstances exactly balancing one another. On the other hand, he lost when at work 145 grams of body weight, and when at rest gained 49, consisting entirely of carbon, hydrogen, and oxygen. At work he absorbed 1,006 grams of oxygen, and at rest 709. A small ill-nourished man, enjoying a liberal diet and rest, gained 202·9 grams in weight, of which again only 0·63 gram was nitrogen.

We have hitherto assumed that a man has all three classes of food-stuffs at his command as well as water and salts, but it is an important question how far a human being can subsist on any two, *i.e.*, on a diet composed of albumin and fat, or albumin and carbohydrates alone; the former being absolutely represented by a purely flesh diet, and the latter approximately by some vegetable diets, as those composed solely of cereals and fruit. The tissues being constructed of nitrogenous materials, some nitrogenous food, *i.e.*, albumin, is evidently necessary, and since we have seen that fat is a product of the splitting up of albumin it is theoretically possible that the animal organism can be maintained on albumin alone. But practically it is for many reasons impossible, the chief of these being the fact already pointed out that an excess of albumin stimulates metabolism to such a degree that while enormous quantities are required to provide the necessary amount of carbon, the waste of body substance still exceeds the supply.

The question then resolves itself into the possibility of dispensing with one or other of the non-nitrogenous food-stuffs, not with both. Thus certain races do maintain their existence on albumin and fat without any carbohydrates, but even they gladly avail themselves of the carbohydrates whenever they can. The inhabitants of South Greenland cultivate potatoes during their short but hot summer, and the Eskimos generally are eager to barter the products of their seas for flour. Many agents of the Hudson Bay Company have been known to subsist for an entire winter on raw fish without any addition. No doubt the cold climate and out-door laborious life enabled them to assimilate such a diet better than they could in more temperate regions, and dire necessity compelled them to be satisfied with it; but of this we may be certain, that, putting aside these exceptional cases, the use of carbohydrates, as well as of fats and albuminates, is necessary for the full development of the human organism in health and vigour of body and mind, though even

in more temperate climates men can, for a time at least, like the hunters of the Pampas, subsist without them. Open air life and muscular exercise are, however, indispensable for the digestion of a purely flesh diet; while, as between fats and carbohydrates, it would seem that the former are the best heat producers in the coldest and the latter are more easily and completely assimilated in warmer climates.

As to the other alternative of a diet of albumin and carbohydrates only, it is no doubt theoretically sufficient, but we have still less opportunity of observing the practical result, for even purely vegetarian races make use of milk, butter, and vegetable oils.

In the diet of purely carnivorous animals fat alone fulfils all the functions of the non-nitrogenous food-stuffs, as starch apparently does in that of the herbivorous, but even grass and roots contain a little fat, and many seeds a large proportion, while, among the carnivora, dogs, at any rate, are the better for a more mixed diet than they could obtain in a state of nature.

As to the interchangeability of natural albumins, peptones, and gelatin, there has been much difference of opinion, but the general conclusion to be drawn from recent investigations, seems to be that while both peptones and gelatin are more easily metabolised than albumin itself, the peptones can but the gelatins cannot, serve for the repair of the tissues; though no less imposing on the kidneys the elimination of urea and uric acid. Gelatin may be a source of energy, but its highest function will be that of saving the tissues from waste in the absence of a proper supply of natural or peptonised albumin.

Effects of an Excess or Undue Preponderance of one or other of the Food-Stuffs

Excess of albuminates induces rapid metabolism, and if their elimination be not aided by active muscular exercise and the increased respiration attending it, a state of plethora, *i.e.*, an excess of fluid albumin in the system,

ensues as the first effect ; next the blood becomes loaded with the products of more or less imperfect nitrogenous metabolism, uric acid and urates appearing in excessive proportion in the urine, with febrile symptoms, and perhaps diarrhœa ; lastly, if the powers of assimilation be still further overtaxed, unchanged albumin passes by the kidneys.

Excess of fats or of carbohydrates has the opposite effect of lessening metamorphosis of tissue, and if digestion be unimpaired, fat is stored up ; otherwise these food-stuffs undergo changes in the alimentary canal with the development of fatty or of lactic acids respectively, and the symptoms known as biliousness, acidity, and dyspepsia. Fat is generally less easily digested than starch, and when taken in excess, much of it passes unaltered in the fæces. Butter is the best assimilated, and the animal fats are more digestible than the vegetable. Indeed, under exposure to extreme cold, and with great muscular exercise, almost any amount of animal fat can be utilised.

Deprivation of albuminates, if sudden, compels the organism to metabolise its own albumin, first reducing the vigour and resisting power which is closely connected with the store of fluid albumin, and next leading to loss of weight. The habitual ingestion of an insufficient amount of albumin gradually reduces the bulk of the muscles and the strength, until equilibrium is restored. Persons of ascetic habits may thus attain to old age, and even possess great intellectual power, but they are incapable of muscular fatigue, and easily succumb to disease or unfavourable external circumstances. Deficiency of non-nitrogenous foods is equivalent to a relative excess of the nitrogenous, accelerating waste of the tissues ; the effects of a deficiency of fat are not very clear, but may be inferred from the improvement that follows its administration in states of mal-nutrition, in the form, for example, of cod-liver oil.

Composition of the Principal Articles of Food

Flesh of Animals.—Speaking roughly, raw meat of ordinary quality consists of water 75 per cent., albumin and other nitrogenous matters 20 per cent., and fat 5 per cent. The albumin exists for the most part in the form of myosin, which coagulates spontaneously after death, this coagulation constituting the so-called *rigor mortis*. After a time the coagulated myosin undergoes further changes, aided by a moderately high temperature, and softens. Meat is tough, and not eaten except in very warm climates, until the rigor has passed off. The coagulation is due to the presence of lactic acid, which gives to raw meat a faintly acid reaction. Besides myosin, muscle contains a small proportion, two per cent., of serum albumin, soluble in cold water, but coagulated by heat. Myosin is almost entirely soluble in acids, being converted into acid albumin, and alkalies act in an analogous manner. Ten per cent. is also soluble in solutions of common salt. These facts have an important practical bearing on the preparation of beef tea, meat extracts, and soluble meats, and in the process of salting, which will be discussed in their proper places. Except in excessively fat meat, the proportion of albumin is fairly constant, any moderate increase of the fat being usually balanced by a diminution of the water present in the meat, as will be seen by the tables in Appendix D.

Although meat becomes more tender by keeping, or hanging, as it is commonly called, it is most wholesome soon after *rigor mortis* has passed off, and freshness should not be sacrificed for a tenderness really due to incipient decomposition. The flesh of mature cattle, *i.e.*, four or five years old, is more nutritious than that of younger ones, and the cultivation of large breeds, which at two or three years have attained the size of the adults of other kinds, is therefore to be deprecated, however profitable to the farmer. It is a matter of experience

that beef and mutton are more easily digested than veal and pork, but this statement requires some qualification, as regards mutton and veal. The former, if too fat, is often not well tolerated, and veal is digestible enough in itself, though the unformed gelatinous tissue with which it abounds gives it a sticky consistence, interfering with its proper mastication. Veal broth, however, contains more nutriment than mutton broth or beef tea, and at the Munich hospitals, where dietetics are studied more scientifically than perhaps anywhere else, "prepared veal," *i.e.*, veal minced and cooked with meal, &c., is much used for convalescents.

In mutton fat stearates predominate ; it is therefore hard, white, and soon gets cold. The fat of bacon consists largely of oleates, and is consequently always soft and oily. The yellow fat of beef again owes its character to the palmitates which hold a middle place as regards fusibility and softness.

The relish of well-cooked meat, shown to perfection in beef roasted before an open fire, is due to the development by the heat of various sapid and odorous substances collectively known as osmazone. That of game and hung mutton is, on the other hand, produced by commencing decomposition, a condition that can be permitted without ill effects only in the case of wild animals and sheep bred on dry mountain pastures, whose flesh is comparatively dry, or parts with its moisture quickly.

Poultry and Wild Birds, if young, yield a tender and highly digestible flesh, though very tough when old. The well-known indigestibility of goose, and to a less extent of duck, is owing to the large proportion of fat infiltrating the muscular tissue.

Fish vary much in their digestibility, salmon being utterly unfit for weak stomachs, the fibre of the cod hard, and that of soles and whiting among the most tender. Salmon, herrings, and sprats have a fair amount of fat. Eels have at least twice as much fat as albuminous mat-

ters, an important consideration, since their muscular fibre is tender, and invalids are frequently partial to them. The majority of fish in ordinary use are almost devoid of fat, though some less known are much richer.

Crabs and **Lobsters** are notoriously indigestible, and not rarely disagree, partly from their being such foul feeders. Perfect freshness is indispensable, the products of their earliest decomposition being specially poisonous. **Oysters** and shell-fish generally, if fresh and clean, are wholesome, nutritious and digestible, especially if uncooked, but may be the means of conveying the infection of typhoid fever, if the beds be near the outfalls of sewers.

Milk is the sole nourishment provided by nature for the young of man and beast, and contains all the food-stuffs in the best proportions for the infant's needs; but milk alone is not adapted to the adult. Apart from the excess of water, the disproportionate amount of albuminates compared with carbohydrates tends to induce a metabolism too rapid for the adult, though desirable in the growing organism. But as an article of diet, supplemented by carbohydrates from other sources, it is invaluable and not appreciated as it ought to be. Some persons, it is true, cannot digest it, at least in bulk, but such inability indicates an abnormal state of the digestive organs. Asses' milk differs chiefly in the form of the nitrogenous constituents, of which a larger proportion are present as serum- or lacto-albumin, and are therefore more easily digested. Mares' milk is not used, even by the nomads of Asia, except in the form of koumiss, being in itself an active aperient.

Condensed Milks are of two kinds, those to which cane sugar is added, and the unsweetened; both are concentrated to one-fourth of the original volume by gentle boiling, aided by diminished atmospheric pressure in so-called vacuum pans. Those to which 30 per cent. of sugar has been added may be exposed to the air for an indefinite time without undergoing decomposition, but the unsweetened will not keep for more than a few days after

opening, according to the mode of preparation and the external temperature.

Cream varies much in composition; it consists of the fat globules which rise to the surface, together with much of the albumin, &c. Heat followed by cold aids its separation, as in the "Jersey" apparatus, and when strongly applied, as in making Devonshire cream, coagulates the serum albumin. The best cream is now made by machines, the milk being run into cylinders revolving several thousand times per minute, the lighter fatty matters collecting in the centre. The supply of milk and the withdrawal of the separated products are conducted uninterruptedly.

Skim Milk contains the water, sugar, casein and salts, but very little fat. Curds and whey, junket, "sauer milch," &c., are milk in which the casein has been coagulated by rennet, or, in the case of "sauer milch," by commencing lactic fermentation.

Butter consists of the fatty matter of the milk caused to cohere in masses by agitation; sometimes from bad making much of the fluid part is retained. Such butter speedily becomes rancid. The addition of from 2 to 5 per cent. of salt serves to defer rancidity for a time, but 10 to 20 per cent. are occasionally added, with a view of covering incipient rancidity, or of enabling the butter to retain more water.

Smalt is butter melted by heat until the whole of the water with the sugar, casein, &c., sinks to the bottom. It is a pure fat, and remains unaltered for many months. Rancidity is caused by the formation of volatile products of butyric acid, and the rankest butter may be purified by fusion and agitation with jets of superheated steam.

Cheese consists of the casein coagulated by rennet, with or without the fat. The "full" leave nothing but whey, *i.e.* water, sugar, and salts, but the "thin" are made from skim milk or from the residue left after the manufacture of butter. The former only undergo the process called ripening, *i.e.*, the formation of ethers of the fatty acids. The latter do not ripen but merely lose water, and

dry up or spoil on keeping. Sometimes cream is added to the milk, and the cheese is described as "double," *e.g.* Stilton. It was formerly believed that in rich cheeses a portion of the casein was converted into fat, but the increase in the fat is only apparent and relative, being due to the loss of water altering the percentage of the remaining constituents. Cheese is highly nutritious but not very digestible, the ploughman living in the open air may derive from it more nutriment than from meat, but the townsman may not be able to utilise it. Being by itself difficult of mastication and comminution, it should always be eaten with bread.[1]

Eggs resemble milk in composition, except that they contain less water. With some persons eggs cause urticaria. Hard-boiled they resemble cheese from a dietetic standpoint. The superiority of new-laid eggs consists in the fact that the albumin becomes less digestible every day.

THE BREAD STUFFS

From the earliest ages certain species of grasses known as **Cereals** have provided mankind with the greatest part of the carbohydrates, and with no small proportion of the albumins. Wheat has always been the most esteemed, and with justice, for it combines a high average proportion of albumins and carbohydrates, with the further advantages of easy trituration, absence of adherent husk, and the property of making a light and spongy bread. One or other variety is adapted to every climate except the very hottest and the coldest. Barley, rye, and oats, can be grown much further north, but they present a far coarser structure, and are therefore less digestible ; and oatmeal is incapable of being made into bread, since its glutin does not form a firm tenacious mass. Rye-bread,

[1] Grated cheese is, however, capable of being cooked in various ways, in puddings, &c., and Mr. Mattieu Williams has shown that it can be completely liquefied by warming with 1 or 2 per cent. of carbonate of potash.

on the other hand, is heavy, dark, and sodden, with a sourish taste. Great part passes off undigested, and it is apt to induce disorders of digestion. It is rapidly being displaced by wheat, except in the less hospitable regions of Northern and Eastern Europe, where it is still used by the poorer classes, and known as black bread. Barley has almost entirely fallen into disuse as an article of food, being grown only for the purposes of the brewer and distiller. In the tropics, especially in the old world, rice is the chief cereal. It is the poorest in gluten and fat, consisting almost entirely of starch. It is thus unfit for bread-making, and is eaten simply boiled. Added to wheat flour it enables the bread to hold more water. The small proportions of albumin and fat unfit it for a staff of life, unless either animal food or pulse be taken at the same time. Thus the natives of India use lentils, dhurra, &c., which are given even in the prisons, for the attempt to maintain existence on rice alone, as was once tried in great Indian famines, is but a slow starvation. Oatmeal, too, so long as milk could be had *ad libitum*, supported a sturdy race of Highlanders, but will not do so under altered circumstances. Maize is of all the cereals the nearest approach to a perfect food, and in former days the slaves of the Southern States of North America flourished on a diet almost limited to it, with batatas and pine-apples occasionally added. Various other grasses, as millet (*sorghum*), are used in Africa and India especially; and buckwheat, a plant of the spinach tribe, yields a coarse, but highly nutritious meal, still employed by the poor in Russia and elsewhere.

Pulse, *i.e.*, peas, beans, lentils, &c., are highly nutritious. They contain 22 per cent. to 24 per cent. of albuminates, chiefly legumin, and were they more digestible would more than equal meat, the place of which they actually take among many Eastern nations. Lentils are not only the most nutritious but also the easiest cooked and digested; still, for outdoor labourers, "haricots" and

"butter" beans, as well as lentils, would, with some melted fat, be an excellent substitute for the butcher's meat they cannot obtain. The vaunted revalenta and nutroa consist essentially of lentil meal. A few other preparations of the cereals may be mentioned here. "Cornflour," or as it is more correctly called in America, corn starch, consists of the starch of maize, from which the glutin has been removed. Hominy, on the other hand, contains all the nutriment of the Indian corn. Pearl barley is an excellent substitute for rice, and more nutritious; it requires, too, less care in boiling, having no tendency to form a gluey mass. Groats or granulated oats are well known, but in America and Germany wheaten groats are used, and are more delicate and digestible. Semolina is a finer kind of wheaten groats made from a hard grain. Sago from the pith of a palm, tapioca from the root of the jatropha, arrowroot from the roots of various plants, belonging to the genera of maranta, curcuma, smilax, &c., are all starches of different degrees of fineness. Maccaroni is prepared from the flour of the hard Calabrian wheat worked into a paste with water and white of eggs, moulded and dried; in Italy and in Germany, where it is called "nudel," it is made in every kitchen.

The Italian **Polenta,** a favourite dish with the peasantry for at least 2000 years, is a porridge made with Indian corn and chestnuts, though anciently of chestnuts only.

Bread and **Baking** will be treated of in the chapter devoted to the preparation and the cooking of food. All the cereals can be used in the forms of porridge or pudding, but only wheat and rye are suitable for bread.

Vegetables

Garden Produce includes a number of roots, green stems and leaves, immature flowers, fruits, and seeds, to which may be added a few ripe seeds occasionally used as vegetables. Some of these are important articles of

food in themselves, others are valuable chiefly for the salts and sapid substances they contain.

Potatoes.—Among roots the potato holds the most prominent place. It contains from 20 to 25 per cent. of nutriment, but this is almost entirely starch, so that the potato cannot succesfully take the place in the dietary of a people, that oatmeal, maize, and lentils do in that ot some races. It is inferior even to rice, which is insufficient alone to maintain health for any length of time; but while the cereals and pulse require some small addition of fat or albumin from other sources, the man who chooses potatoes as his carbohydrate must obtain the whole of his albumin and fat elsewhere. Doubtless the fact that the potato will yield a greater weight of food from the same area than any other crop leads the Irish and Polish peasantry to rely so rargely on it. They should, however, be urged to supplement it with whichever may be within their reach of such equally one-sided foods as cheese, lentils, or beans for albumin, and bacon, butter, or margarine for fat

Potatoes, too, are wholesome only when the starch granules are healthy, as shown by their swelling out during boiling, bursting their envelopes and converting the whole into a floury mass easily broken down. Young potatoes composed of immature cell-tissue and unformed starch are less digestible and nutritious; but those in which the starch has undergone subsequent changes from disease or commencing growth, are in the highest degree indigestible, and should not be eaten at all. Unfortunately, English people seem to look on all vegetables except this as mere ornaments or luxuries, and see no alternative between bad potatoes and no vegetable whatever.

Parsnips, with 16 per cent. of food stuffs, mostly sugar, beetroot, Jerusalem artichokes, and carrots with little less, should be used much more than they are. The first, though too sweet for some persons, become more pleasant

to the taste after exposure to frost, at a time when potatoes are deteriorating. The woody fibre of carrots and parsnips is most abundant in the paler central portion of the root, so that those which have the largest proportion of the softer outer coat—itself wholly the effect of cultivation—are the best. Carrots, though containing much sugar and pectin or vegetable jelly, are not very digestible; and turnips, with less nutritive matter even when young, become traversed by woody structure when old.

Cabbages and their allies can scarcely be viewed as food, for the greater part of their carbohydrates exists in the form of cellulin, which, when mature, is as indigestible as in its familiar form of paper, though in the earlier stages amenable to cooking and digestion. But the real value of greens is to be found in the salts they contain, and as an anti-scorbutic few things equal cabbages. Spinach is the most digestible of all greens, its tissues being extremely loose, and it possesses a peculiar flavour disliked by some persons, but highly appreciated by others. French Beans belong dietetically to the same class, but must be young; and the same is true of asparagus. Vegetable marrows and other gourds are digestible and pleasant, but do not possess much value as food properly so called.

Onions and Leeks are chiefly employed as flavouring. They contain large quantities of a highly sapid volatile oil, into the composition of which sulphur enters. In digestion offensive compounds of this element are formed which betray themselves by the odour of the breath, and are apt to disagree with some persons.

There are three vegetables much used in Germany, but which are scarcely known in this country, though ranking high in nutritive value: Kohlrabi, a kind of cabbage, the succulent stalks of which are eaten, and the globular roots of scorzonera and of a peculiar variety of celery, all of which deserve cultivation.

As regards green vegetables in general, the importance of

having them fresh is not sufficiently realized. When they have been cut some days, changes, less perceptible indeed, but not less real than those which occur in animal tissues take place, leading to derangements of digestion; and this incipient fermentation is accelerated by the practice of market gardeners, who give a false appearance of freshness by wetting the leaves. The cartloads of cabbages sent to market are frequently the accumulation of several days.

Pulse, *i.e.*, peas and beans, are more generally used in the green state, in which they do not differ much from other green vegetables, containing 75 per cent. to 80 per cent. of water. They are highly nutritious, and, if young enough, are very digestible; but while the demand for early green peas tempts the growers to bring them into the market even before their nutritious constituents are fully formed, it is unfortunately otherwise with broad beans as they are called. These ought always to be eaten before the hilum or point of attachment has become dark-coloured, and while they cannot be boiled without bursting their skins. At this stage they are tender, digestible, and nutritious, and with a little melted butter furnish an ample and complete meal even without meat.

Salads are useful as anti-scorbutics, but many of them are very indigestible. Among the most so are radishes and celery, as well as cucumbers. Lettuce, if young and blanched, salsify, watercress, and mustard and cress, provided they are young, are much more easily digested. Radishes contain sulphur compounds allied to those in onions, and produce like after-effects.

Mature cellular tissue, however comminuted, is absolutely refractory to digestion, and together with the spiral vessels can be recognised in the fæces. Thorough mastication renders the mass less irritating to the bowel, and liberates the more nutritious matters contained in the cells. The laxative action of green vegetables is due partly to the salts and partly to the mechanical stimulation of the bowel by the fibre.

Fruits are prized chiefly for their taste, which they owe to the grape and fruit sugars, the vegetable acids, tartaric, racemic, citric, and malic, and certain ethereal oils. They contain also, besides the sugar, small quantities of pectose or vegetable jelly. They are, however, not without dietetic value, though grapes alone among fresh fruits contain any large proportion of food stuffs, for the sugar and acids have a gentle laxative action, aided in some cases by the mild irritation caused by seeds and cellulose; and the vegetable acids, free or combined with alkaline and earthy bases, are the very best of anti-scorbutics. Fruits should be fully ripe, but without any trace of decomposition. Those that can keep should be carefully preserved from bruising, while the soft and perishable kinds cannot be too fresh, since if rudely handled and heaped together they quickly undergo fermentive changes. Dates contain much starchy matter as well as sugar, and constitute a substantial part of the food of some peoples, as do the fruits of the banana, bread-fruit, &c., in default of cereals. Dried figs contain 54 per cent. of sugar, &c., and 4 per cent. of albuminates. But it is for the acids, salts, and sugar that fruits are valued in European countries.

Fruits are eaten to best advantage, both as regards enjoyment and dietetic benefits, at breakfast or between meals, as in Germany, Italy, and southern lands generally. After a heavy dinner is the most undesirable time possible. The leaf stalks of rhubarb, rich in oxalic acid, rank dietetically rather with fruits than with vegetables.

Summary of Chapter I.

The tissues of all living organisms are composed of complex nitrogenous and non-nitrogenous organic bodies, the former comprising albumins and gelatins, the latter the fats and the carbohydrates, so called from the H and O being present in the same proportions as in water, H_2O, together with earthy matters and water. Plants build up their tissues with N and C drawn

from the earth and air, whereas animals which, whether growing or not, are constantly undergoing waste and repair, require their pabulum in the organic forms presented by the tissues of plants or of other animals. **Carbohydrates** are almost restricted to the vegetable world, fats are more abundant in the animal, and albumins, though in different forms, are common to both. **Albumins** compose the muscle of meat, the white of eggs and the curd of milk, the glutin of cereals and the legumin of pulse. The **gelatins** also contain nitrogen, but are not available for tissue building. The **fats** include stearin, peculiar to animals, and palmitin and olein common to them and plants, the consistence of a fat or oil depending on the relative proportions in which these are present.

Carbohydrates comprise the sugars and starch, which is convertible into glucose, also gums, and intermediate bodies as dextrine. All foods contain some mineral matters, as lime, potash, soda, and iron, collectively described by analysts as ash.

The popular division of foods into animal and vegetable is unscientific and misleading, save as regards the absence of carbohydrates from the former, with the exception of milk.

The uses of food are (1) the repair of the tissues and (2) the evolution of energy in the forms of (*a*) animal heat, and (*b*) exercise of function; in other words, foods serve for repair and for fuel, the analogy between the animal and the steam engine being closer than was supposed by Liebig when he compared it to an engine consuming itself in its work. Muscular exercise is attended by some wear and tear, but the true source of heat and energy is in the burning or oxidation of food as fuel, as is shown by the great increase in the oxygen absorbed and the CO_2 given off during hard work, not of the urea and uric acid which represent the ordinary waste of tissue, and the metabolism of nitrogenous food; the quantity of albumin in the food should be determined by the general muscular development; the carbohydrates and fats, being oxidised into CO_2 and H_2O only, are better fuels than albumin, which is excreted as urea and uric acid. Some albumin is indispensable for the maintenance of the body, and theoretically, as having a high potential energy, nothing else is necessary, but a purely albuminous diet can be borne only when oxidation and excretion are exceptionally active: otherwise the blood becomes laden with effete products of imperfect metabolism. Either fats or carbohydrates may be dispensed with without serious effects, but fats seem preferable when there is a great demand for muscular energy and heat production, and both are necessary for perfect nutrition. The potential energy of a food-stuff is estimated by the heat evolved

in its combustion, but this hypothetical value is not borne out by experience. Excess of carbohydrates, and in a less degree of fats, tends to obesity, not that they are converted into fat, but because being more easily oxidised they permit of the less complete metabolism of the albumin, which then breaks up into urea and fat, of which it is the true source. Deprivation or great restriction of carbohydrates compels the organism to use up the albumin, and also its own fat, as fuel, and is the principle of Bantingism, &c.

Deprivation of fresh animal and still more of fresh vegetable food, especially of the vegetable acids, induces a disease of malnutrition known as scurvy; and deficiency of fat, and in a less degree of albumin, especially in dark ill-ventilated dwellings, leads to rickets in infants.

Raw meat consists of albumins 20 per cent., mostly myosin, insoluble in water, with a little serum albumin, soluble in cold, but coagulating in hot water; fat 5 to 25 per cent. or more, the rest water. **Fish**, except salmon, herrings, sprats and eels, are almost devoid of fat. **Game** and the drier muttons are, unlike other meats, wholesome when "high," while pork and fish are the most poisonous.

Milk, casein and albumin, 5 per cent., fat 4 per cent., sugar 4 per cent., is a **perfect food for growing infants and convalescents**, but has too large a percentage of albumin and water for others. In that of ruminants there is most casein, but in asses' and human milk most albumin, an important dietetic distinction; the casein not coagulating by heat but forming hard curds in the stomach.

Cream is a variable mixture of fat globules, albumin, and some of the fluid part of the milk. **Butter**, the fat in a nearly pure state. **Cheese** is the coagulated casein with or without the butter fat, changes in which constitute the so-called "ripening." Cheese if "full," *i.e.*, with the fat, is highly nutritious, though indigestible, except when grated.

Cereals contain albumin [glutin], 10 to 15 per cent., but only half this proportion in rice. Maize and oats contain 4 to 6 per cent. of fat, but wheat 1 to $1\frac{1}{2}$ per cent., and rice less than 1 per cent., the starch amounting to 65 to 75 per cent., and in rice to 80 per cent. Oats and maize give the most ash, 2 to 3 per cent.; the rest but 0·5 to 0·75 per cent. Pulse, *i.e.*, peas, beans, and lentils, are richer in albumin [legumin], 20 to 24 per cent., and poorer in starch 58 per cent., the fat and ash being as in oats and maize. From their large percentage of albumin they take the place of meat in the diet of some races.

Potatoes contain 75 per cent. of water and 22 per cent. of starch and cellulin; they are anti-scorbutic, but their food value is greatly over-rated. **Green vegetables** and roots, and fresh fruits contain 10 to 20 per cent. of nutriment, grapes 24 per cent. of sugar, but their salts and the acids of fruits give them all anti-scorbutic properties.

QUESTIONS ON CHAPTER I

1. What food elements or constituents must be present in every diet so as to maintain health? Upon which of the constituents does the power of performing work chiefly depend? 1900, E.

2. What amounts of proteids, fats, and carbohydrates are required in a standard diet for ordinary work? Calculate the amount of lean meat, butter, and bread which would be required to furnish these. 1900, A.

3. What is the composition of cows' milk? How can adulterations be detected? 1900, A.

4. In what respects do human and cows' milks differ most materially, and how far can the latter be "humanised"?

5. Which of the three "foodstuffs," proteids, fats, and carbohydrates can or cannot be dispensed with? How far are the fats and carbohydrates interchangeable?

6. State the source of fat in the living body. Explain fat formation as an apparent result of excessive consumption of carbohydrates, and the effect of restricting them in the treatment of obesity.

7. What is lime juice? Explain its use. 1899, E.

8. What is the composition of lemon juice, and to which of its constituents are its beneficial effects as an adjunct to food attributable? To what standards should it conform, and how would you determine whether it do or not? 1898, H.

9. What are the carbohydrates? Give their chemical composition and classification. Discuss their value in nutrition. 1898, H.

10. What is the composition of beef? In what respects would a diet of 1 lb. of bread and 12 oz. of meat per diem be deficient? 1898, A.

11. What amount of fat is contained in an ordinary diet?

How is it disposed of in the system? What are its effects on the intestinal canal? 1884, A.

12. Why is common salt a necessary food? Whence is it obtained? What other important mineral salts are contained in foods? 1885, E.

13. Discuss the value of gelatine as an article of food. How much carbon and how much nitrogen are contained in an average diet? 1885, A.

14. Compare the flesh of fish with butcher's meat as food. Mention some important differences in the flesh of various kinds of fish. 1886, E.

15. What food substances especially aid the action of the intestines? What is the importance of regular action. 1886, E.

16. What is meant by the "digestion coefficient"? Give some examples of the utilisation and the waste of animal and vegetable proteids and of several qualities of breads. Is a wholly digestible diet to be desired? and what are the effects of approximations thereto?

17. Compare and contrast the various cereal grains as to their composition and economic uses. 1886, A.

18. What are ultimate products of the metabolism of proteids, fats, and hydrocarbons in which they are eliminated? By what emunctories do they leave the body?

19. How much work in foot tons can be expected from a diet consisting of cooked beef 10 oz., bread 24 oz., butter 1 oz., and potatoes 20 oz. 1887, H.

20. A man is required to perform 300 foot tons of external work. How much available energy must be present in the food, and what should be the relation of the different food stuffs in his diet? If the work should be increased to 450 foot tons, to what extent must the available energy be increased? 1899, H.

21. What is the composition of cows' milk? Discuss its value as an article of diet [in infancy and in after life]. Explain the changes which it undergoes when kept, and state what part it plays in both the prevention and the propagation of disease. 1893, H.

22. Which is the more nutritious, rice or pea-flour? Upon what do their relative qualities depend? 1894, E.

23. What are the functions of nitrogenous food? Mention the chief nitrogenous principles met with in foods, and their relative values as nutrients. 1894, A.

24. What is the general composition of fat, and how does it differ from that of sugar? What is meant by the digestion of fat; when and how does it take place? 1895, A.

25. What is the average percentage composition of a starch? What is arrowroot, from what sources is it obtained, and how are its varieties recognised? 1895, H.

26. What is cheese, and how prepared? What is the nutritive value of the several classes?

27. Milk is the only single article of food that can be described as "perfect." Under what conditions is this true, and why is it not so under others?

28. Analyses of meat extracts give sometimes the percentage of proteids, and at others that of nitrogenous matters or of nitrogen. Which give the better estimate of the nutritive value, and why?

29. Discuss the respective values of fine white, whole meal and brown bread, from the chemical and the physiological standpoints.

30. What part, if any, do the indigestible constituent as woody fibre, take in the process of nutrition?

31. What value as foods and in the maintenance of health attaches to fruits in general and to such as oranges, figs, bananas and grapes in particular?

32. What are the characters of nuts as regards nutritive value and digestibility?

33. What is the special value of salads in diet?

CHAPTER II

STIMULANTS, CONDIMENTS, ETC.

No substance irremediably nauseous, or for which the human palate refined or depraved cannot acquire a taste, can be habitually used as an article of food, however nutritious in itself. Even the absence of taste soon creates a feeling of repugnance, and the same flavour which once stimulated the appetite palls, if continued without interruption. Taste and a variety of tastes is

necessary to the enjoyment and even to the retention and digestion of foods, and such variety can be to a great extent attained by a judicious interchange of the ordinary articles of food, all of which, either by themselves or as usually combined, possess more or less flavour. But besides the foods properly so called, there is a large class of substances of little or no nutritive value, and prized chiefly or solely for the agreeable impressions they make on the taste, or smell, or on the nervous system generally. Such are the various alcoholic beverages; tea, coffee, and cocoa; vinegar and some other acids; condiments and spices, including certain herbs, all more or less pungent or aromatic substances, owing their characters to volatile oils; and lastly, sweets or sugar alone or associated with water, acids, &c. Sugar is of course as much a food-stuff as starch, but is used chiefly to impart a flavour to the more insipid carbohydrates, and most fruits are valued rather for their flavour than their nutritive properties, except among races who depend on the native products of the soil.

For these very various substances we have no collective name. "Accessory foods" has been proposed, but is not satisfactory. The Germans call them *Genussmittel* or means of enjoyment, as contrasted with the true foods which they call *Nahrungsmittel* or means of nourishment. Some of them, as the osmazone and sapid substances developed in the cooking of flesh, and the sugar and acids present in fruit as well as the oils of savoury herbs, are ready to hand, but the intensity of the craving for such sensory impressions innate in the human constitution may be judged by the price which rich and poor will give for them, when so much more nutriment might be had for the same money.

Their action on the digestive organs and the nervous system is real and complex.

The simplest is that of condiments and spices, stimulating the secretion of the saliva and gastric juice, and thus aiding digestion, though, if indulged in to excess,

acting injuriously, rendering the gastric glands insensible to the gentler stimulus of plain food, and even inducing a state of chronic catarrh of the mucous membrane. Such is frequently the result of the habit among Europeans in tropical climates, of stimulating the jaded appetite with curries, chilies, &c.

The actions of thein and of alcohol are more complex, being exerted on the great nerve centres, and will be considered later on. For the relations of alcohol to sugars and starches see p. 8.

Alcoholic Drinks

have from the earliest ages been prepared by man from any and every form of sugar or starch. The juice of the grape and numerous other fruits, the starch, previously converted into sugar, of cereals, potatoes, and several roots, the saccharine juices of the sugar cane, maple, palm, &c., and the milk sugar of mares' milk, being employed in one or other part of the world.

Alcoholic drinks may be roughly divided into fermented and distilled, the former including beer and wines, consisting of the saccharine fluid, or must, with more or less of the sugar converted into alcohol, together with some free or unconverted sugar, other nitrogenous and non-nitrogenous vegetable matters, vegetable acids, free or combined as alkaline and earthy salts, and perhaps tannin and colouring matters. The finer kinds contain also certain ethers, to which is due the "bouquet" of wine; the alcohol is almost exclusively ethylic.

Distilled alcoholic drinks, or spirits as they are called, consist solely of alcohols, ethers, and water, the volatile constituents of the ordinary fermented must. Brandy, (in German *branntwein*, or burned wine) was originally obtained by distillation from the commoner sorts of wine. It is still so made in some parts of France, and is known as Cognac, but the greater part of the brandy in the market is distilled from malt or potatoes. Whisky and gin are obtained from the must of barley malt, the

latter owing its peculiar flavour and diuretic properties to the addition thereto of juniper berries, some of the oil of which akin to turpentine passes over. Rum is distilled from molasses or the uncrystallisable, and therefore less valuable, part of the sugar extracted from the cane by boiling. Arrack is prepared in India and China from rice, while in Eastern Europe Kirschenwasser from the cherry and Slivovitza from the plum, in Africa spirits obtained from the palm juice, and in America from the maple, agave, &c., furnish local and national beverages.

One grand distinction may be drawn between those distilled from sugar itself and those from converted starch ; viz., that the former, cognac and rum, contain ethylic alcohol only, whereas the latter, the commoner brandies, whisky, &c., have more or less of higher alcohols, especially amylic, and other bye products, collectively designated fusel oil, and are far more injurious, especially when new, for after some years, the fusel oil breaks up to a great extent into comparatively innocuous bodies. The proportion of fusel oil is greater in the low priced whiskies, in which for the sake of cheapness more or less raw corn is added to the mash, than in those made from malt only.

New wine is often highly intoxicating, to an almost poisonous degree, from the presence of aldehyd, which, however, becomes speedily oxidised into acetic acid.

The colours of wines, though frequently artificial, are properly due to the retention, or otherwise, of the skins of dark grapes during the process of fermentation ; that of beers, to the degree to which the sugar in the malt has been altered by the heat employed in drying it. The colour of stout and porter is farther deepened by the addition of burnt sugar, liquorice, &c.

Distilled spirits are all necessarily colourless when first made, and the distinguishing tints of whisky, pale or brown brandy, and rum are purely conventional, and obtained by the addition of less or more burnt sugar.

Liqueurs consist of alcohol, sugar, and essential oils.

ALE, BEER, AND STOUT.

Beer.—The recent analyses of malt, by Valentine and O'Sullivan, show that the proportion of sugar is much greater than was formerly supposed. Roughly stated, the 65 per cent. of starch in the barley is represented by 45 per cent. of starch and 20 per cent. of sugar. The brewer transforms the whole, or nearly the whole, of the remaining starch, by steeping it in hot water, adding a certain quantity of yeast to set up fermentation. There are different ways of doing this, the principal being the (1) *surface* fermentation practised in England, in which the starch is transformed by successive *infusions*, and the fermentation is conducted at 15° to 18° C. (60° to 66° F.), the yeast floating on the surface, and being removed by skimming; (2) in Germany the transformation of the starch is affected by *decoction*, and sedimentary yeast (*Unterhefe*), which sinks to the bottom, is used. The temperature, too, is lower, 12° to 14° C. (53° to 57° F.), and the clear supernatant liquid is drawn off, but since all the yeast has not been deposited fermentation continues for some time afterward (*Nachgährung*), which causes the beer to be well charged with carbonic acid. The best "Lager Bier" is now made by Pfandler's process, conducted throughout in vacuo, or in sterilised air. The formation of lactic acid does not occur in well-conducted fermentation, but only when fermented liquids become sour and ropy.

The bitter taste is given to beer by the addition of hops, sun-dried in Germany, but kiln-dried and blanched by fumes of burning sulphur (SO_2) in England. Notwithstanding the prejudice in favour of the latter, based on its appearance, there is no doubt that much of the delicate aroma is dissipated in the process of kiln-drying and bleaching.

The **German Beers** contain less alcohol than the English, and are less bitter, but they are richer in

carbonic acid. They are, moreover, far less apt to become sour, or as it is called, hard, than ours. Of the German the Bavarian is the mildest, containing but 2 per cent. of alcohol, and possesses a fine aroma. The lager beers are the strongest.

German beers have of late been received with much favour in this country and exported largely to India, where they are fast superseding the stronger "India Pale Ales" so-called. The Anglo-Bavarian Brewery Company, at Tottenham, too, supplies a tolerable imitation of the commoner "Lager Bier," but Messrs. Allsopps now brew a genuine "Lager" by Pfandler's process.

Bottled Ales owe their sparkling character, as do champagne and similar wines, to being bottled while fermentation is still proceeding.

Name of Beer.	Malt Extract.	Alcohol.	Carbonic Acid.	Water.	Analyst.
Porter, Barclay and Perkins	6·0	5·4	0.16	88·44	Kaiser.
Burton Ale	14·5	5·9	...	79·6	Hoffmann.
Edinburgh Ale	10·9	8·5	0·15	80·45	Kaiser.
Berlin Ale	6·3	7·6	0·17	85·93	Ziurek.
Munich Bock Bier	9·2	4 2	0·17	86·49	Kaiser.
,, Lager (16 months old)	5·0	5·1	0·15	89·75	,,
,, Schenk Bier (draught)	5·8	3·8	0·14	90·26	,,
Brunswick ditto	5·4	3·5	...	91·1	Otto.
Prague ditto	6·9	2·4	...	90·7	Balling.

J. König gives as the mean of numerous analyses the following :—

	Water.	Carbonic Acid.	Alcohol.	Alb.	Extract.	Ash.
English Ales and Porters	88·52	0·21	5·16	0·73	6·32	0·27
German Double or Export Beer	88·72	0·25	4·07	0·71	7·23	0·27
,, Summer Beer	90·71	0·22	3·68	0·49	5·61	0·22
,, Winter Beer	91·81	0·23	3·21	0·81	4·99	0·20

Malt Substitutes.

We have referred to beer as a product of the fermentation of malt, but this can be properly applied to German beers and those of Alsopps, Bass and a very few of the highest class of breweries. The great majority of brewers use large quantities of glucose and inverted sugar prepared by the action of sulphuric acid on maize, &c., and such beers are less wholesome, while if crude acid be used they may contain arsenic as an impurity.

It is as an alcoholic drink that beer is chiefly or solely valued; but it will be seen from these tables that the quantity of nutriment in it—6 to 8 per cent., and in some kinds 10 to 15 per cent.—is by no means inconsiderable, consisting of "malt extract," so called, or maltose, dextrin, and other bodies of the sugar class. The drowsiness induced by beer is partly due to the oil of hops, for wines of the same alcoholic strength do not possess the same stupefying action. The stronger, sweeter, and darker ales, as Burton, Scotch, &c., are made by prolonged boiling of a concentrated wort, but the density of stout and the heavier porters is obtained by the addition of treacle, sugar burned to different degree of blackness, linseed, and liquorice. The propriety of such additions is a matter of taste, but there is a more serious objection to the use of other saccharine matters together with malt, since they tend to irregular fermentations and acidity.

Wine.

Wines are the fermented juice of the grape. The must is not boiled as beer wort is, nor is yeast added, fermentation arising spontaneously from germs present in the air of wine growing districts, and adhering to the skins of the grapes. Red wines owe their colour and astringency to the colouring matter in the skins of

the black and brown grapes, and the tannin in the seeds which are left in the must during fermentation. In the manufacture of white wines, on the other hand, white grapes only are used, and the expressed juice is strained before being put to ferment.

The sugar and the free acid in the must are usually present in inverse proportion, the actual quantity differing greatly with the region and the soil, but even in the same place the percentage varies with the season—that of the sugar from 12 per cent. to 24 per cent., and that of free acid from 0·5 per cent. to 1·2 per cent.

During fermentation a part or the whole of the sugar is converted into alcohol. Various ethers giving the characteristic bouquets are formed, also succinic acid, and other bodies of less moment. Acetic and malic acids may be generated, the former by irregular fermentation, the latter when the grapes are imperfectly ripened, as in cold damp seasons. When the whole of the sugar is destroyed the wine is said to be dry. Sparkling wines are obtained by bottling before fermentation is complete, or occasionally, in Germany, by forcing carbonic acid gas into a still wine as in the manufacture of aerated waters. The characteristic acid of the grape is tartaric, thence called in German (*Weinsäure*) wine acid. Some of this is retained in the wine, but much crystallises in the casks, as bitartrate of potash, the so-called cream of tartar. New wine contains aldehyd, a highly intoxicating agent. This soon undergoes further oxidation into acetic acid, of which traces exist in all wines, though when light wines are exposed to the air the whole of the alcohol is in course of time converted into this acid, and wine vinegar is thus made.

On the question of the alcoholic strength of natural wines much misconception exists. It cannot be too strongly insisted on that when during the fermentation of a saccharine solution, the alcohol reaches 14 per cent., fermentation is thereby arrested, and that conse-

quently any excess of alcohol over that percentage must necessarily have been added subsequently. In other words, the wines has been fortified by common spirit. In Prussia thousands of acres are devoted to the cultivation of potatoes, the best of which are used for home consumption or exportation, while the refuse are employed in the distillation of spirits to be methylated for trade purposes, or used for the manufacture of brandy, gin, &c., the fortification of natural, and the production of the spurious wines, which form a larger proportion of those in the market than the uninitiated would suspect.

A few words as to the names under which the clarets are sold may not be amiss. The produce of the vineyards scattered over South-West France is taken to Bordeaux, the place of exportation, and there branded by a class of hereditary wine-tasters as first, second, or third quality. A few—very few—honourable wine merchants in London retain these descriptions, but the vast majority substitute the titles of St. Julien, St. Estèphe, Château Margaux, &c., as synonymous. This can scarcely be considered a fraud, if the meaning be understood; but it must be remembered that the actual produce of these famous estates does not go beyond a favoured circle of royal and other great families. So with other special vintages. Château Latour is made by adding nuts or almonds, and Château Lafitte by adding almonds and violets to ordinary Bordeaux wines. This, however, is a totally different thing from fraudulent fabrications.

The same conventional nomenclature is employed, though in a somewhat different way, with the wines of Germany. In that country the produce of each district, whether a single hillside or an entire province, is named after the locality where it is grown; but many of these are never heard of here, the wines of these vineyards being named by our merchants after those better known to which they bear the nearest resemblance.

It is otherwise with Spanish and Portuguese wines, which, with very few exceptions, are all called alike Sherry or Port from whatever part of the peninsula they may come, or whether they are manufactured by dilution, fortifying, colouring, plastering, &c., from others, good, bad, and indifferent, collected from all parts of the Mediterranean.

Strongly alcoholic and fortified wines are slow to

change, but the lighter, if not all natural wines, are prone to acetification on exposure to the air, and cannot be drawn from the cask for use as required, unless a flask of fine Lucca olive oil be emptied on the surface, when the film of oil, effectually precluding the access of the germs which set up the change, serves to preserve the wine unaltered for many weeks.

The relative proportions of alcohol, acid, sugar, &c., in some of the more important wines, are shown in the following table taken from König :—

Wines.	Alcohol.	Free Acid.	Sugar.	Tannin and Colouring Matter, &c.
Red Wines—				
Red Rhine Wines, mean . . .	10·08	0·52	...	0·16
Hungarian ditto, mean . . .	9·65	0·59	...	0·13
Burgundy ditto, mean	11·15	0·53	...	(?)
Bordeaux ditto, mean	9·07	0·59	...	0·22
White Wines—				
White Rhine Wine, mean . .	11·45	0·46	0·37	
Moselle ditto, mean	12·06	0·61	0·20	
Riesling ditto, mean	12·90	0·65	0·01	
Sweet Hungarian Natural—				
Tokayer Ausbruch, . . .	12·74	0·52	14·99	18·34
Ruster Ausbruch, . . .	11·08	0·51	21·74	23·64
Fortified Wines—				
"White" Port, ...	20·03	0·54	4·88	8·83
Red Port, ...	21·91	0·45	6·42	8·83
Sherry, ...	22·90	0·44	1·88	3·78
Madeira, ...	19·11	0·48	3·46	5·22
Marsala	20·44	0·39	3·48	4·94
Malaga, ...	16·14	0·42	16·47	21·23
Sparkling Wines—				
Champagne (*carte blanche*). .	11·75	0·58	11·53	13·96
Sparkling Rhine Wine	12·14	0·57	8·49	12·14

At the English customs houses the alcoholic strength is estimated as "proof spirit," and since this means spirits consisting of alcohol 49·24 per cent. and water 50·76 per cent., the figures next following, if halved, will represent the real alcoholic strength as given in the preceding

tables. Such are those of the undermentioned natural wines.

Burgundies,	21·5	Rhenish,	21·9
Clarets,	17·75	Bavarian,	21·3
Beaujolais,	20·8	Hungarian, lighter,	21·8
Hermitage,	22·0	,, stronger,	24·0

	Natural State.	Slightly Fortified.	Fortified for English Market.	As Sold in the Shops often.
Sherries, Amontillado, &c.	27·2	30·7	35·7	38 to 45
Port	23·5	33·6	35·4	

A perfect wine may be described as one possessing all the characteristic properties, flavour, aroma, and exhilarating action of wine, but in which neither alcoholic pungency, acidity, sweetness, nor astringency is sufficiently marked to offend the most delicate palate. Such are the finer Rhine wines, Burgundies, clarets, and a few others. Some wines are, on the other hand, decidedly acid, sweet, or astringent, especially the inferior kinds. Sugar is added to the fortified wines of Spain and to champagnes, but some of the Greek wines are naturally so rich in saccharine matter as to be positively syrupy. The taste affords by no means an accurate estimate of the acidity or of the amount of sugar present, for these may mask one another. For example, Dr. Dupré found the following quantities of sugar in grains per bottle

Natural Rhine wines, 8·64, 1·44, and in two others mere traces.
Natural Bordeaux, 13·56, 15·62, 18·48, and 11·40.
Natural Sauterne, 125 (this was distinctly sweet).

In fortified wines—

Sherries, 307·8, 217·2, 356·4, and 421·2.
Ports, 519·7, 460·8, 190·2, and 121·2.
Marsala, 388·8 and 451·2. Champagne, 500.

In the same wines the free acids were—

Bordeaux, 77·40, 72·96, 74·28, and 65·76.
Rhine wines, 67·44, 57·60, 70·32 and 69·24.
Hungarian, 80·16, 85·92 and 83·88.
Sherries, 55·32, 54·48, 61·16, and 58·08.
Ports, 49·56, 49·56, 62·16, and 58·08.
Marsalas, 39·12 and 46·76.

Again, a light claret contained only 6·08, while an old expensive sherry had 5·18 parts per 1000 of free acid, but the latter had 29·7 per 1000 of sugar.

Astringency, if marked, is a real defect. Tannin has no *tonic* properties, but while small amounts have no effect on digestion, an excess is certainly injurious. In old ports the tannin tends to separate along with the colouring matter and to adhere to the bottle, leaving the fluid "tawny."

The fixed acids or salts of wine consist largely of tartrates of potash and of lime; the former most abundant in Bordeaux and port, the latter in Rhine wines. Sherry is remarkably deficient in both, from being "plastered" or treated with sulphate of lime (plaster of Paris), to precipitate the albumin, &c., and hasten the clearing of the liquid, a practice greatly to be deprecated on account of the depressing action of the sulphate and the loss of the tartrates. The value of the phosphates has been absurdly exaggerated.

The mutual reaction of the acids and the alcohol leads to the formation of ethers, fixed and volatile, to the latter of which wines owe their superiority to ordinary diluted spirits as stimulants and exhilarants. Those of Hungary have the largest proportion of volatile ethers though the finest vintages of France and Germany approach them in this respect. The dosing with spirits and plastering, to which Spanish wines are subjected, greatly interfere with the development of ethers, though some few fine ports and sherries are by no means deficient in them. But even the best ports are more or less

artificial products, being largely made up of Greek and other wines, sugar, spirit, and "jerupiga," a spirituous syrup of elder and phytolacca berries, &c., especially when the vintage is under the average.

The Greek wines, rich and possessing a fine aroma, are however mostly too sweet to please the English taste. The fine wines of Italy are rapidly winning a well-deserved favour, but were formerly shipped to France to be remade and disguised under well-known French names. Cape wines have long lost their popularity from defects of manufacture. The Australian wines, carefully prepared from the produce of the best vines transplanted from Germany and Hungary, are for the most part unadulterated and rich, though wanting in delicacy, and the Californian are all that could be desired.

In conclusion, we may observe that though it is possible to make true wines from many juices besides that of the grape, as *e.g.*, gooseberry, currant, orange, rhubarb with sugar, &c., the orange, ginger, and other "British wines," as commonly sold, are simply forms of "grog" or "toddy," *i.e.*, mixtures of coarse spirit, sugar, and flavouring matters, and not wines in the true sense of the word.

Cider is properly called apple wine in Germany. In it malic takes the place of the tartaric acid, and it has a decidedly aperient action. Perry is a pear wine, but mead prepared from honey is wanting in acids, ethers, and salts, and therefore resembles rather a liqueur.

Koumiss is an alcoholic, acidulous, and effervescing beverage originally prepared by the Bashkirs and other nomad races of the steppes north of the Caspian, from the milk of a breed of mares devoted exclusively to this use. The Russian physicians, who have a high opinion of its value in wasting diseases, have greatly improved on the mode of manufacture, and have succeeded in preparing it from cows' milk. The ferment employed by the nomads is obtained from the sediment of former brewings, but a mixture of beer yeast with wheat flour,

lentils, and honey, is found to answer the same purpose. The process of fermentation lasts about thirty hours, during which the percentage of alcohol formed is from 1·1 to 4, and lactic acid from 1 to 3, the milk sugar disappearing. Dr. Vieth and other dairy chemists have, however, further modified the procedure and obtained a koumiss of a far more stable character, not attaining its full alcoholic strength until after several weeks. These processes are trade secrets of the companies, but a full description of the composition, preparation, and uses of koumiss in general is to be found in the article by Dr. Stanger in Ziemssen's *General Therapeutics*, vol. i.

THE USE AND ABUSE OF ALCOHOL

This question is one which it is hard to approach with perfect impartiality. It would be a waste of words to insist on the physical, moral and social evils of intemperance, whether it take the vulgar form of open drunkenness or the more decent though insidious one of constant tippling. With regard to the former, Dr. Baer of Berlin, who is no rabid teetotaller, has adduced an overwhelming mass of statistics from every civilised country, to show that pauperism, crimes of violence, &c., are in direct proportion to the consumption of spirits—wines and beers being from this point of view comparatively harmless. Generally speaking, habitual indulgence in excessive quantities of alcohol of any kind, though never carried to the degree of intoxication, is productive of ruinous consequences to the digestive and other functions ; especially if taken on an empty stomach, or in too concentrated a form. Irritation of the mucous membrane of this organ leading to catarrh and congestion of various degrees of intensity, loss of digestive power, and perhaps hæmorrhages from the engorged vessels. Irritation of the liver, causing congestion and fatty degeneration, or when alcohol is taken in the form of spirit, especially if neat, a peculiar and

invariably fatal interstitial inflammation called cirrhosis; similar lesions of the kidney; general disturbances of nutrition, shown in some cases by emaciation, but more frequently by fatty degeneration of all the muscles and organs, and notably of the heart, a frequent cause of death; softening, *ie.*, fatty degeneration of the brain, apoplexy from rupture of its degenerated vessels; gout, gravel, stone, &c., &c.; to which we may add an indefinable want of power to resist acute disease, or unfavourable external conditions of any kind. On the other hand, it is equally certain that in health and under perfectly natural conditions of existence, alcohol in any form is not a necessity. Men are capable of the greatest bodily and mental exertion without it, and in extremes of heat and cold they are certainly better without it provided, in the latter case at least, they have proper food. The Russian soldier, though as a peasant addicted to the use of coarse brandy, is provided on the march with tea only. The North American trapper strictly abstains from alcohol during the day when exposed to cold and fatigue. In the tropics, alcohol, in its stronger forms, is especially injurious. On the other hand, after great fatigue, its value is indisputable, and it may enable men to perform extraordinary exertion provided they can enjoy rest at its close. It does not raise the temperature of the body, the glow it seems to produce is only superficial, caused by dilatation of the cutaneous vessels, in consequence of which the body parts more rapidly with its heat. It accelerates the action of the heart, but this acceleration is followed by a reaction. It also in moderate quantities induces sleep. All these actions have their time and place, when they are desirable; at others they are not so. It undoubtedly checks metabolism, and many extravagant statements have been made, even by some really eminent men, as if this process could not be too active, whereas we have seen that the acceleration of metabolism caused by an excess of albuminates induces emaciation;

and one of the most important functions of fat, &c., is to counteract this. Habitual excess in alcohol, especially concentrated, leads in this way to fatty degeneration of the organs, notably the heart, liver, and kidneys : but so does excess of hydrocarbons, a moderate use of which is essential to health.

The most telling examples urged by teetotallers of the uselessness of alcohol, are drawn from the experience of soldiers on active service ; of athletes and great pedestrians ; of students of the universities, &c. ; but these are just the men who can well spare it in the flush of health, in the prime of life, and free from the cares and worries of existence. Even the well-paid artisan has less anxiety than the merchant, the barrister, or the hard-working student of mature years. To these, after the labours of the day, a moderate amount of alcohol in the form of a light and natural wine is sometimes felt to be a boon, if not a necessity. In old age again, when the heart is weak, the richer stronger wines, or even pure spirits, are occasionally no less valuable, and far from shortening may prolong life. But they should never be taken during work with the idea of urging the brain to greater exertion—rather, if at all, when the day's labour is over to check waste, to compose the brain, to remove the sense of fatigue, and induce a cheerful calm and a quiet sleep. Indeed, as Dr. Gairdner, than whom it would be hard to name a more judicious authority, writes, "Amid the wear and tear, the fag and worry, the disjointed and imperfect machinery of human life, we believe that alcoholic drinks are at times a very necessary medicine, at times a very useful help, at times a very enjoyable and harmless luxury, and in none of these respects are we willing to disown them when honestly tested by experience and kept within bounds by reason and prudence."

Alcohol should never be taken fasting, nor early in the day—the proper time is at a late dinner or supper. The brain worker's light luncheon is not a fit time, unless he cannot eat

without; and for those who dine early, the rule is to ask whether a glass of beer or light wine increases, diminishes, or has no effect on the appetite. If the first, it does good: if the last, it is useless though harmless; but if it lessen the appetite, or seem to serve as a substitute for food, it is an unmixed evil.

Is alcohol in any sense a food, *i.e.*, does it undergo metabolism, or combustion in the organs of the body, with evolution of heat or some other form of force; or does it pass out of the body unchanged, as copper, mercury, and some of the vegetable alkaloids? The latter view is still maintained by the reckless opponents of its use in any shape, and the conclusions of Lallemand and Duroi are constantly appealed to, though long ago shown to be utterly fallacious. These experimenters, if they deserve the name, dosed men and animals with enormous quantities of alcohol, and because they could detect a certain amount in the urine, &c., inferred that none was consumed. The fact is, there is a limit to the power of the organism in the case of alcohol, as of fat, which if given in excess appears in the fæces; and it would be no more unreasonable to assert that cod-liver oil is not a food, because if more than a few ounces be given in one day, much of it is thus passed out unassimilated. Every substance in the process of metabolism ministers either to nutrition of tissue, or to the evolution of heat or force, and it is a well-ascertained fact that an average man can so dispose of one ounce to one ounce and a half of absolute alcohol in the day that no trace of it shall be discoverable in the excretions. But if more than this be taken, the excess can generally be detected in the urine.

Taking one ounce of absolute alcohol per diem as the permissible dose, we may easily calculate the quantity of any given alcoholic beverage which most men may indulge in with impunity, by the tables of percentages given above. One ounce of alcohol is contained in two of spirit (50 per cent.); in five to ten, *i.e.*, a quarter to half-a-pint of the more alcoholic wines (10 per cent.

to 20 per cent.); in half-a pint to a pint of the lighter wines and stronger beers (5 per cent. to 10 per cent.); and in a pint and a half of the lighter ales (3 per cent. to 5 per cent.) It is better that only one or two kinds of alcoholic beverages be taken during the day; the stronger should never be taken except on a full stomach, and spirits should always be freely diluted, since otherwise they enter the portal circulation in too concentrated a state, and act as direct irritants on the liver. Indeed, they may before absorption so irritate the mucous membrane of the stomach as to induce chronic if not acute catarrh or inflammation. Spirits, too, are as a rule more hurtful than wines or beers, from their liability to contain by-products of fermentation, which, as Brockhaus demonstrated on himself are far more poisonous.

Of course the mere fact of the organism being capable of metabolising that amount of alcohol proves nothing as to the physiological consequences, good or evil, which must be determined by observations of another kind.

Much has been said by teetotallers as to the presence of alcohol after absorption in the blood, which they assert is no longer pure blood but a mixture of blood and alcohol,—just so might it be said that after eating pickles or a rhubarb tart, it is a mixture of blood and vinegar, or blood and oxalic acid that circulates through the brain, and oxalic acid is a well-known poison! Every soluble substance taken into the stomach passes into the blood, and must exist there as such until it combines with the tissues, or undergoes metabolism, unless it be incapable of either process, when it is sooner or later eliminated. Quinine, morphia, mercury, and other drugs belong to the latter category; while the therapeutic and dietetic value of acids, alkalies, salts, and iron, which belong to the former, depends on the more or less profound alterations they effect in the ever-varying constitution of the blood. Alcohol is broken up in the organism into carbonic acid and water, previously acting on the central nervous system, first as a gentle stimulant, and if in larger doses afterwards as a sedative, may be as a narcotic.

Aerated Waters

are either natural, as the original seltzer and apollinaris waters; or artificial, as soda water, lemonade, &c., and artificial seltzer. They are essentially waters highly

charged under pressure with carbonic acid, though they usually contain also a variable quantity of alkaline salts; or may, like lemonade, be flavoured with sugar, citric acid, &c. The addition of carbonate of soda enables a larger volume of the gas to be dissolved, but it is not essential and the best kinds contain the least. The popular prejudice against their use is unfounded, unless, indeed, in excess. But the acid of lemonade is apt to dissolve lead if the apparatus be provided with pewter fittings, or as is sometimes the case, leaden pipes are used.

Tea, Coffee, and Cocoa

It is a remarkable fact that in three different continents men have from time immemorial used the leaves or seeds of plants, having not the remotest mutual resemblance, but which chemists have recently discovered to contain the same active principle, and that the beverages thus prepared have become actual necessaries of life to all but the most barbarous races.

Tea, the cultivation of which was till lately confined to China and Japan, though now extending rapidly and widely in India; coffee, said to have been first used in Abyssinia, but long grown throughout the tropics; and the so-called Paraguay tea (*Ilex paraguayensis*), contain identically the same alkaloid Theine or Caffeine. That in cocoa differs slightly, and is called Theobromine. Tea and coffee contain also tannin, gummy matters, and volatile oils, to which the aroma and some of the physiological effects are due. There is also no inconsiderable quantity of fixed oil in coffee. The arguments urged against the moderate use of alcohol in health, that it is a poison, and foreign to the organism, might be urged with equal justice against indulgence in tea and coffee.

The leaves of the so-called Paraguay tea (*Ilex paraguayensis*) have not yet found their way to the European market, though much used in South America. The

leaves of the coffee tree contain less caffeine, but more of the bitter principle than the seeds, and are preferred to the latter by the natives of Sumatra and Java.

In the unroasted coffee bean the oil is enclosed in cells and appears under the microscope in the form of fat globules. These are broken up, suffused, and partly dissipated in the process of roasting, which also chars the sugar and gum and develops sapid bodies. The beans improve in flavour by keeping for several years, even ten or twelve, but should be used as soon as possible after having been roasted.

The different qualities of teas depend, for the most part, on the age of the leaves and the soil and aspect of the plantation. Black and green teas are made from the same plants, the colour being due to the preparation; the former having been subjected to a process of fermentation and roasting, "firing" as it is called, the latter dried when almost fresh; and the Japanese teas simply sun-dried. Natural green teas are rather of a brownish hue; the bright green tint of some is artificial, and the result of facing with various pigments which may or may not be harmless. The colour of black tea is also frequently heightened by facing with the so-called black lead, as used for blacking stoves. The names pekoe, souchong, congou, &c., are given to the successive gatherings, each being stronger and coarser than the preceding. Scented teas owe their fragrance to the addition of the leaves of the *Olea fragrans*, &c. The best teas do not yield the darkest infusion, some of the choicest, rarely seen in this country, but in great request in Russia, giving a pale amber liquid.

Both tea and coffee should be used in the form of infusion, though coffee may be allowed to boil for a minute or two after infusion. Prolonged boiling dissipates the aroma, and extracts too much of the astringent matter. Of the total weight of coffee employed, from 21 per cent. to 37 per cent., according to the kind and the degree of

roasting, including on an average 1·75 per cent. of caffeine, passes into the infusion. Of tea, about 33 per cent., with 1·35 per cent. of theine is dissolved, but these figures do not represent the actual strength of the resulting infusions, since it is usual to employ three times as much of the former. Indeed, coffee to be palatable must be strong, and the only dilution that does not spoil it, is with hot milk, whereas weak tea is a pleasant beverage. Thus, a large cup of coffee made from 15 grams of the ground berries contains about 0·26 grams of caffeine, and one of tea made from 5 grams of the leaf, only 0·07 of theine. The total soluble matters in the former amount to 3·82 grams, in the latter to 1·68 grams.

Tea and coffee act alike as excitors of the nerve centres, accelerating and strengthening the heart's action and respiration, causing wakefulness, and increasing the secretion of the kidneys and skin. The alkaloid being among the bodies excreted as uric acid, they have been erroneously supposed to check nitrogenous metabolism. Coffee stimulates the peristaltic movements of the bowel, so as to be for some persons an active aperient. Taken in excess they induce sleeplessness, headache, palpitation, tremor of the muscles, and impaired digestion, the last effect being probably owing to the tannin, and most marked when tea has stood under a cosy or on the hob. Some persons are more susceptible to the effects of tea, others to those of coffee. The aromatic oil to which the finer qualities of both tea and coffee owe their virtue, is a gentle sedative ; the loss of this as well as the presence of an excess of tannin explains the injurious effects of strong decoctions of tea.

Tea and coffee, like alcohol, should not be taken fasting, nor except in moderation as stimulants to work, though for the latter purpose they are far less hurtful than alcohol. "Afternoon teas" before a late dinner, though better far than wine drinking at that time, are not quite innocent.

The Japanese allow the infusion to stand not more than one or two minutes when they pour it off into a second pot. Such tea needs no milk and may be drunk all day with impunity.

The effect of theine on the circulation in the brain is the reverse of that of alcohol : hence the use of coffee after dinner, a tacit admission that too much alcohol has already been imbibed. Tea and coffee are far superior to alcohol in enabling the organism to resist the depressing influence of fatigue and exposure to cold, &c., and are admirably adapted to the needs of soldiers on the march, or men on outdoor night duty.

Cocoa and its preparations contain, as we have said a similar active principle, but the proportion of nutritive material in cocoa is so much greater, that it is to be looked on rather as a food than as a drink.

The cocoa bean has the following mean composition according to König :—

Water	3·25%	Other non-nitrogenous substances	12·35%
Nitrogenous matters	14·76%	Woody fibre	3·68%
Fat	49·0 %	Ash	3·65%
Starch	13·31%	Theobromine	1·6 %

Cocoa nibs are the roughly broken beans. Flake cocoa is the same crushed between rollers. Prepared cocoas have half or more of the fat removed by pressure and heat. Soluble cocoas are freed also from woody fibre. The cheaper cocoas of the shops are largely mixed, or it would be more correct to say adulterated, with starch and sugar to the extent of 20, 40, or even 60 and 80 per cent. of their weight, which, considering the large proportion of starchy and allied bodies in natural cocoa, is a perfectly uncalled-for addition. Though cocoa fat is remarkable for not being liable to rancidity, the natural proportion—nearly 50 per cent.—is too much for most persons, and its partial removal is a real improvement. When this has been done, cocoa may be

looked on as almost a perfect food, containing the due proportion of albumin, fat, and carbohydrates. The addition by the consumer of sugar to cover, if desired, the bitter taste, and of milk, does not materially alter its composition. The greater bitterness of Caraccas cocoas is owing to the beans having been laid in heaps or in trenches to ferment. Chocolate consists of the entire cocoa bean finely ground and mixed with sugar, and various flavouring substances, of which the favourite seems to be Vanilla. It is, however, subject to great adulteration.

VINEGAR

Vinegar is a dilute acetic acid formed by the action of a special ferment on alcohol; the process being one of oxidation, first into aldehyd and then into acetic acid. The best is made in France and Germany from wine; malt is, however, the chief source of vinegar as of spirits, and it is occasionally obtained by the distillation of wood. Wine, malt, and fruit vinegars contain besides from 2 per cent. to 7 per cent. of the acetic acid, varying quantities of sugar, dextrin, &c., and wine vinegar retains also the bouquet or volatile ethers, on which account it is the most prized.

Coarser cheaper vinegars are frequently adulterated with sulphuric acid, of which the excise allows ·01 per cent., though there is no good reason even for this. British manufacturers of malt vinegar produce four qualities or strengths, containing from 3 per cent. to 4·6 per cent. of acetic acid. Malt vinegar is of a decided brown colour (though this may be imitated by adding burned sugar), and contains dextrin, &c., and salts, chiefly sulphates and chlorides.

Wine vinegar varies from straw colour to red, according to the character of the wine. It has a vinous odour, and contains tartrate of potash.

Used in moderation, vinegar is at least harmless, and may assist digestion. It has been found of use as a preventive of scurvy, though very inferior to lime juice. But in excess, and especially when adulterated with sulphuric acid, its effects on digestion are most injurious. It also renders the cellular tissue of pickled vegetables hard and indigestible in the highest degree.

Spices, Condiments, and Seasonings

Of all these, especially the more pungent, as mustard, pepper, cayenne pepper, and fresh capsicums, it may be said generally that so long as they are used only as relishes to impart a just perceptible flavour to food they may help the appetite and digestion, though the perfectly normal stomach should be able to dispense with them. But when taken in excess they easily induce catarrh of the gastric mucous membrane, and if they are habitually indulged in, so as to become indispensable, as among Europeans resident in hot countries, the nerves of the stomach which excite the secretion of the gastric juice become insensible to the gentle stimulus of the mere contact of food, and at length fail to respond even to the strongest irritation.

Ice

The habitual use of ice and iced drinks is to be deprecated. Small quantities are of service in relieving thirst and vomiting and in cooling the body when exposed to great heat ; but since ice causes the mucous membrane of the stomach to become temporarily pale and bloodless, it checks or altogether suspends its secretion. Thus iced drinks at meals interfere seriously with digestion, and at other times the reaction following the driving of the blood out of the vessels tends to induce secondary congestion of the mucous membrane, to say nothing of the shock to the ganglionic nerve centres. We may take

this opportunity of exposing the fallacy of the vulgar notion that ice water is always pure. Water is not purified by freezing, and may even be more charged with pollution as ice than it was before, the cold arresting the self-depurating action of decomposition and oxidation as has several times been shown in America by the poisoning of households.

Summary of Chapter II.

Alcoholic beverages contain ethylic alcohol formed together with CO_2 from the sugar, or the starch converted by malting into malt sugar, the ferment of beers being yeast (*Torula cerevisii*), and those of wines and cider one that adheres to the skins of the fruit. **Beers** contain alcohol 2 to 8 per cent., with 3 to 14 per cent. of "malt extract." **Wines**, alcohol 9 to 12 per cent., or if "fortified," to 20 per cent., sugar 0 to 20 per cent, some free tartaric acid; and red wines 0·5 to 2·3 per cent. of colouring matters, tannin, &c., derived from the skins. If bottled while fermentation is proceeding, much free CO_2.

Spirits distilled contain 40 to 50 per cent. of ethylic alcohol, and if from starch (malt) other by-products called "fusel oil."

Alcohol is a stimulant for good or ill, in excess narcotic; habitual excess leads to degeneration of the tissues, especially of the brain and liver. The sensation of warmth is illusory, being due to increased cutaneous vascularity tending to loss of body heat.

Tea and coffee contain the same alkaloid caffein, also oils, tannin, and gummy matters. Action complex, nervous and cardiac stimulants, not followed by reaction or narcotism, but in excess causing irritable heart, &c., and the tannin impairing digestion; great excess may intoxicate—formerly believed to check albuminous metabolism, but this is an error based on misinterpreted phenomena. **Cocoa** contains a similar alkaloid, theobromin, also nitrogenous matters 15 per cent., fat 50 per cent., starch 13 per cent., other non-nitrogenous matters 12 per cent.; in fact, 90 per cent. of food.

QUESTIONS ON CHAPTER II

1. What are the physiological effects of alcohol used in moderation, and in excess? 1886,E.

2. What is the composition of cocoa? Compare it with coffee as a food. 1884,E.

3. State what you know respecting the composition, and the effects of (1) tea, (2) coffee, and (3) beer as drinks. 1893,E.

3. What are aërated waters? What impurities are they likely to contain, and why? 1895,A.

5. Is ice purer than water?

6. Describe the English method of brewing beer, and explain how it differs from the German. Explain the theory of fermentation. 1894 and 1898,A.

7. What is the essential difference between wines and beers as regards the means by which their fermentation is induced? To which class would you refer cider?

8. What is the highest percentage of alcohol in a "natural" wine? What is the natural acid of wines? What is meant by a "dry" wine?

9. How, and from what materials, are spirits derived? What is meant by "fusel oil"? What spirits are most apt to contain it?

10. What is meant by "plastering" wines? What is the purpose of the process, on what wines is it most practised, and in what respects are they deteriorated thereby?

11. What is koumiss? What do you know of its preparation and constitution?

12. What has given rise to the notion that tea and coffee check nitrogenous metabolism? Give the true explanation.

13. What is the difference between the different kinds of teas in the market? and to what do the very black and really green teas owe their colours?

14. What general objections and what special dangers attach to the use of glucose in place of malt in brewing?

15. To what constituents do tea and coffee owe (1) their common and (2) their distinctive properties?

16. How are "bottled" ales and "sparkling" wines produced? How may still wines be converted into sparkling?

CHAPTER III

Cooking and Preparation of Foods

This is not a cookery book, and we shall confine ourselves to the consideration of a few general scientific principles which underlie the whole subject, though imperfectly understood or appreciated by many adepts in the details of the art. Man is most decidedly omnivorous, but there are few products of the animal or the vegetable kingdom, except milk, eggs, oysters, and fruits, that he is capable of digesting properly in their raw state.

The aim of cookery is not merely to pamper the appetite, but to render food more digestible as well as more palatable; yet while the latter end is usually attained, the former is not unfrequently defeated from the want of a scientific knowledge of the composition of the food, and the effects of heat and moisture on its several constituents, as well as of the *modus operandi* of the digestive act.

The effect of heat and moisture on meat is to coagulate the albumin (that of water at a lower temperature to dissolve out a certain proportion), to convert the connective tissue into gelatine, and, by dissolving this, to loosen the fibres and render them more amenable to the action of the gastric juice, to diffuse and partly to melt out the fat, and finally to develop odorous and sapid bodies. Meanwhile the contraction of the coagulated albumin expels a large part, about 20 per cent., of the water

contained in the meat, and this equally whether the meat is exposed to the air or immersed in water.

Boiling.—The change in the percentage of the constituents due mainly to the loss of water is thus represented by C. Krauch :

	Water.	Albumin.	Fat.	Extractive.	Ash.
Raw Meat . .	70·88	22·51	4·52	0·85	1·23
Boiled Meat .	56·82	34·13	7·50	0·40	1·15

If raw meat be immersed in cold water and gradually boiled, a large proportion of the soluble albumin and salts passes out into the liquor. Again, if kept so long at the boiling point as to allow of the heat penetrating the meat and raising its mass to a temperature of 170° F. or more, the albumin is rendered hard and indigestible. Both results should be avoided. It is quite true that the solution of the connective tissue may be carried so far that the meat is reduced to "a rag," but the individual fibres are almost incapable of being acted on by the gastric juice, and may be detected with their striated structure unaltered in the fæces.

To boil meat, therefore, without hardening of its interior or the loss of much valuable nutriment, the outer surface should be exposed to a high temperature just long enough to coagulate the albumin to a depth of a quarter of an inch or so, after which the heat should not be allowed to exceed 170° F. This is best effected by plunging the joint into boiling water for five or six minutes, then adding cold water in the proportion of three pints to each gallon of hot, and keeping it at the resultant temperature until the cooking is complete. The loss of soluble matters is thus almost *nil*, and the meat remains tender throughout. Should the more usual practice of putting the joint into cold water be followed the loss

of weight may amount to 30 or more per cent., but in that case the liquor should be used for soups and not thrown away. If allowed to reach 180° to 200° F. the meat becomes tough.

Roasting.—The loss in this case, about 20 to 25 per cent., consists of water and fat. The same "case hardening," as in boiling, is effected by exposure of the joint for a short time to the radiant heat of a bright fire; after which the fire should be reduced, or the joint removed to a greater distance from the fire, and the process continued more slowly. Some water or broth should be placed in the pan below, and with the melted fat and other matters exuding from the meat, be repeatedly poured over it in order to prevent burning or charring of its surface. This is commonly called basting the meat. The effect of the radiant heat is to develop odorous and sapid substances which give the peculiar relish to roast beef.

Baking resembles roasting, but the flavour of the meat is not the same, from the absence of radiation and of free evaporation.

The time required for roasting or baking is about a quarter of an hour for each pound weight for beef, mutton and goose, a little more for pork and veal, and much less for poultry. Before removal some thick fleshy part should be pressed with the finger, to see that it has lost the elasticity of raw or imperfectly cooked meat.

Baking is not open to the same objections when the meat is enveloped in a thick non-conducting crust, or is contained in a pie-dish; and a pie, if enveloped in flannel, or the so-called Norwegian oven, will remain hot, and improve in condition for hours. No better dinner could be desired for fishing parties, &c.

Broiling is roasting on a small scale, equally adapted for meat and fish.

Stewing gives a product too saturated with fat for some persons, unless vegetables are cooked with the meat.

Frying in shallow pans is liable to give an oily dish, charged

with various products of burned fat. The meat should be done lightly, and frequently shifted, that no part may be unduly acted on by the heat. Fish is best fried by complete immersion, *i.e.* boiling in oil, which is drained off when the process is complete. For invalids and persons with weak stomachs, boiling is far the better mode of cooking fish.

Oily fish, as sprats, herrings, and pilchards, are advantageously cooked by baking in a deep saucepan in alternate layers with bread crumbs.

Hashing is the worst use that can be made of meat, which by the two processes it has been put through becomes thoroughly indigestible. Cold meat should be eaten as such.

Soups or **Broths** consist essentially of water containing the soluble but now coagulated albumin of any fresh meat used in making them—the gelatin, extractives, and some of the fat, to which various farinaceous substances and vegetables may be added at pleasure. In invalid cookery the use of farinaceous matters, which form the bulk of the German soups, is too much neglected; the presence of gelatin, in plain language of glue, being considered by English cooks an indication of strength. Vegetables do not need boiling so long as the soups, and should therefore be done separately, and added afterwards; but soup itself is spoiled by being too long or repeatedly boiled. The meat boiled to threads is quite insusceptible of digestion, and should therefore be removed. To get the utmost possible amount of nourishment, *i.e.*, of soluble albumin out of meat, it should be put into cold water, in a finely divided state, and the temperature should not be allowed to reach 170° F., for about four hours. Indeed in making beef tea, if the meat be minced and pressed occasionally, there is no need to apply any heat for that time, after which it may be briskly boiled for twenty minutes to extract the gelatin, &c. Not more than a pint of water should be used for each pound of meat. A concentrated beef juice may be made by putting the meat finely chopped into a wide-necked bottle, closed and kept in boiling water for several hours.

The nutritive value of beef tea and meat extracts has been greatly overrated by medical men as well as by the laity. The best beef tea does not contain more than 1 per cent. of albumin, and the undiluted juice squeezed out of raw meat but 6 per cent. Liebig's extract consists of water 20 per cent., salt 22 per cent., and organic matters 58 per cent. ; but its nutritive value is less than nothing. Its properties are rather those of a stimulant to an exhausted system, in fact, not unlike those of strong coffee, enabling the organism to digest food which without it would have lain heavy on the stomach. There are, however, several preparations which belong to a totally different category. In these the albumin of meat or of milk, with or without the addition of farinaceous matters, has been subjected to the action of pepsin or pancreatin, and adapted respectively to cases in which the gastric or the intestinal digestion is defective. Among these Carnrick's beef peptonoids take the first rank, containing but 6·75 per cent. of water; and Benger's (pancreatised farinaceous) foods are also highly nutritious, while Kemmerich's beef pepton, Valentine's meat juice, and Barff's kreochyle are all superior to Liebig's extract. The so-called "extracts" are in fact excrementitious or waste matters in readiness for elimination by the kidneys, and differ little from concentrated urine. The nitrogen is mostly present in the form of kreatin, kreatinin, xanthin, &c., combinations allied rather to urea than to albumin. They enter largely into the composition of Bovril and Brand's extracts combined with pulverised meat fibre in the former and gelatin in the latter. As to the published analyses of meat extracts, &c., it must be remembered that the percentage of *nitrogen* is perfectly valueless, since unless in the form of albumin, peptons or gelatin, it is no more food than if it represented so much ammonia.

But without question the most valuable of these preparations, and the only one that deserves the name of meat solution, is that (not patented) recommended by Drs. Leube and Rosenthal. The myosin, which is only rendered more insoluble by heat, but which forms the bulk of fresh muscle, though wasted in the ordinary modes of making beef tea or extracts, is, if not previously hardened, soluble in the gastric juice, as when roast or boiled meat is eaten, and also by the combined action of heat and acid which convert it into acid albumin.

Dr. Leube's directions are as follows :—

1000 grammes of beef, free from fat and bone, are chopped fine, and put into an earthenware or porcelain jar, with 1000 cub. centimeters of water, and 20 of pure hydrochloric acid. The jar is then placed in a Papin's digester, fast closed and digested for

twelve to fifteen hours; during the earlier part of the time, the apparatus is occasionally opened and its contents stirred. The mass is then taken out of the jar, and rubbed or beaten in a mortar to the consistence of a paste, returned to the digester, and kept heated under pressure for fifteen to twenty hours. It is now taken out neutralised with carbonate of soda, thus converting the acid into common salt, moistened with water to form a fluid like gruel, and divided into four rations, which are given to the patients, either pure or with crushed biscuit and milk. It makes an excellent soup.[1]

As regards eggs, it may be said without hesitation, that the nearer raw the more digestible they are, and the yolk is more so than the white, which, when hard-boiled, is the most indigestible form of albumin known. The addition of eggs to baked puddings is of questionable utility, and next to a raw egg well beaten in milk or water, or in soup or beef-tea not too hot, a light boiled custard is the best form for invalids.

In boiling vegetables the cellulin is softened and rendered more digestible, the starch cells burst and the granulose is liberated. Of all green vegetables spinach is the most easily digested, being reduced by boiling to a pulp. Potatoes and rice, which consist mainly of starch, require care and skill, in order that they may be thoroughly cooked but not reduced to a glutinous mass. They are best when steamed, but equally good results may be attained by boiling, if, when they are just softened throughout, as ascertained in the case of potatoes by thrusting in a fork, and in that of rice by biting a few grains, the water is poured off, and the saucepan placed on the top of the range or the side of the fire. The operation is finished by evaporating the excess of water. In thus drying off potatoes the lid should be partly lifted, and the potatoes rolled about to prevent unequal drying or adhesion to the saucepan. Rice should be put into a colander let into

[1] Leube's dissolved meat can be had in closed tins of Messrs. H. Poths and Co., 4, 5 and 6, Bury Court, St. Mary Axe, E.C. Each tin contains 1 lb., and costs 2*s*.

the saucepan, and constantly stirred until every grain is separate from the others though perfectly soft. The water in which some of the starch is dissolved need not be wasted. Flavoured with sugar and lemon and iced, it makes a favourite drink in India. It may also be used as a stock for soup.

Potatoes should, unless steamed, be done in their jackets, for when peeled they lose both flavour and the salts which pass out into the water, and to ensure their being equally boiled, they should be all of a size, whether large or small. Haricot (dry) beans are very nutritious, being rich in legumin (albumin) as well as starch. Served with bacon or other fat they make a cheap and substantial repast for persons with good digestions, but they should be steeped in cold water for twelve hours at least (twenty-four or more is still better) before boiling. They should not be more than one year old, or no amount of boiling will make them soft. Broad or Windsor beans, even more than peas, should be young. If they have attained their full size, and the hilum or point of attachment is dark-coloured, they are hard, and their skins leathery and indigestible. They should burst in boiling; if they do not they are past their prime, and have lost their rich flavour. Asparagus should be tied in bundles and placed upright with their green heads out of the water: thus done, the stalks will be boiled soft without the heads being overdone and losing their form and firmness.

Bread-Baking, Raising, &c.

Good plain biscuits, commonly called captain's, are made from fine flour and water only, without salt or any addition. They are too hard for general use, but make delicious puddings, and are the best for babies' biscuit powder.

Fancy biscuits are not only flavoured with sugar and spices, but are lighter and less dense, from the addition

of carbonate of ammonia when made on a small scale, or the forcing of carbonic acid into the dough, or more correctly the paste, in the large manufactories. Milk may be substituted for water, and rice, maize, oatmeal, &c., may entirely or partly take the place of the fine wheat flour.

A quarter of wheat weighing, say 504 lbs., loses, in passing through the mill, about 7 lbs., and the products may be estimated as fine flour 330 lbs., seconds 50 to 60 lbs., middlings 35 lbs., pollard 50 lbs., and bran 26 lbs. Pollard and middlings are divided into fine and coarse, and the flours into pastry whites, Vienna flour, fine or best whites, best and other household, &c. These subdivisions founded on the colour and other properties do not indicate degrees of sifting only, but are partly determined by the quality of the grain employed and the preservation of the flour.

It has been found that flour made from corn harvested in wet weather or which has been subsequently exposed to damp, gives a dark heavy bread, unless a little alum be added ; or as Liebig suggested, lime water be used in place of ordinary water. Wholemeal breads, including ordinary brown and the so-called wheatmeal bread, are made from the products of the entire grain, divested only of the outermost coats or bran, though in practice bakers often make a brown meal by adding pollards to seconds flour. "Wheat meal" is ground between steel rollers, and the fragments of husk having thus no sharp angles, it is less irritating to the intestine than the coarser kinds. The colour of brown bread is due not so much to the branny matter as to the production of maltose, &c. from the starch by the action of the cerealin, a nitrogenous ferment present in the outer coats. If this be destroyed by previously heating the dry flour, a very fairly white bread can be made from whole meal.

Great stress has been laid on the alleged higher nutritive value of whole meal, but the analyses of Mr. Bell seem to show that this is an error. Even chemically it is little richer in glutin than fine flour, and the excess of cerealin is a very doubtful advantage, its effects on the starch being seen to the fullest extent in the brown, heavy, clammy character of rye bread, the black bread of the Continent.

Brown bread is a laxative from the irritant action of the bran on the bowel, and much of it is therefore hurried through the digestive canal and wasted. Wheat meal is less irritating, but it is very doubtful if the mere finely divided state of the woody fibre makes it more digestible. Chemically, indeed, there is no differ-

ence between sawdust and arrowroot, but no grinding would make the former equally amenable to digestion. Probably, after all, the instinctive preference felt for a fine white flour is well grounded. Experimenting on the several wheaten and rye breads of Germany, Rubner found that though more nutriment of every kind was contained in the coarser, much less was assimilated, the loss in the fæces in each being as shown in the following table :—

	Total dry substance.	Glutin.	Starch.	Ash.
Bread from fine flour, 30 % of the grain	4·0 %	20·0 %	1·0 %	14·3 %
" from "seconds," 70 % of the grain	6·7 %	24·6 %	2·36 %	30·3 %
" from whole meal, 95 % of the grain	19·2 %	30·5 %	5·7 %	45·0 %
" rye, moderately fine	15·0 %	32·0 %	11·0 %	30·0 %

The usual baker's formula in England is—Flour 20 lbs., tepid water 8 to 12 lbs. ($6\frac{1}{2}$ to $9\frac{1}{2}$ pints), yeast 4 oz., to which an indefinite quantity of mashed potatoes is added, and $1\frac{1}{2}$ to 2 oz. of salt.

One sack (280 lbs.) of flour will make from 90 to 105 4 lb. loaves, *i.e.*, 100 lbs. of flour yield on an average 130 to 150 lbs. of bread ; if the flour contained originally 14 per. cent of water the bread will contain 33 per cent. in the former and 42·7 per cent. of water in the latter case—$6\frac{1}{2}$ lbs. dough=6 lbs. of bread. The baker's aim is to incorporate as much water as possible without spoiling the appearance, but besides containing less nutriment damp bread sooner turns mouldy. Bread loses some of its moisture, and therefore weight, during the day after baking. To prevent this the baker sometimes keeps the loaves covered with a cloth to check evaporation. Loaves containing an excess of water tend to become sodden below, and may be seen in the shops turned upside down. The best bread should not contain more than 34 per cent., and be uniformly porous without large cavities, and light without being friable ; the crust crisp, not leathery or "withy," as the bakers call it ; and light brown, but not

charred. The best test of quality is perhaps the ease with which thin bread and butter can be cut.

In making bread, the water, warm but not hot, and in the proportion by weight of 5 parts to 12 of flour, should be divided into two parts, one-half as large again as the other. The salt is dissolved in the larger, and the yeast well beaten up in the smaller portion. These are then mixed and added gradually to the flour, which is to be thoroughly kneaded and allowed to stand for four or five hours to rise. When it has reached its height, and before it begins to sink, it is to be made into loaves and put into the oven. Common bakers' ovens are heated by lighting a wood fire within them, the charcoal and ash being swept out when the proper temperature has been obtained; those of the now increasingly numerous "steam" bakeries by the more accurate and cleanly method of hot water pipes. An ordinary kitchen oven will answer well enough, the condition being that the temperature should not be less or greater than that of boiling water, and that it be kept constant or nearly so. The oven should be closely shut for two or three hours, by which time the bread will have attained its full volume, partly by the continued action of the yeast in the interior of the loaf, which does not probably reach a higher temperature than 100° F. (38° C.), and partly by the expansion of the heated gases in its substance. The oven may now be opened from time to time to watch the progress of the baking. If opened before the expiration of the time named the process is interrupted, and the loaves become flattened and heavy.

The raising of bread, which distinguishes it from biscuit, consists essentially in the disengagement of carbonic acid gas in minute bubbles within the mass of the dough, and the subsequent expansion of these bubbles by heat. To effect this three entirely different methods may be followed :—(1) The conversion of the sugar and modified starch of the flour into carbonic acid and alcohol

by the action of the yeast plant, which takes place while the "sponge is being set" prior to placing it in the oven; (2) by the disengagement of carbonic acid from a carbonate by some stronger acid as in baking powders or by heat; and (3) by forcing carbonic acid into the dough from without (Dauglish's patent worked by the Aerated Bread Company). These three are precisely comparable to the effervescence in bottled ale or champagne, a seidlitz powder, and soda-water respectively.

Bread raised by yeast is called fermented, all the others being unfermented. Yeast is of two kinds, corresponding to the two kinds of fermentation noticed in the account of beer. English yeast is a frothy fluid skimmed from the surface of the fermenting wort, containing the mycelium in active growth. German yeast is a dryish putty-like mass, composed of the spores which settle at the bottom of the vat. It is brought over in bags, which require gentle handling. When it is used, a longer time is needed for raising the sponge; in other words, for the germination, as well as the growth of the yeast plant. In either case if the dough be removed to the oven before fermentation is completed, the yeast is killed and the process arrested.

In making bread the starch is converted by heat and moisture into a modified form of paste, and partly into dextrin and maltose by the action of the cerealin. The saccharine substances are broken up by the yeast into alcohol, which passes off, and carbonic acid—the glutin rendering the dough more cohesive than starch paste alone would be, checks the escape of the gases and vapour. The small amount of glutin in rice, and the peculiar form in which it exists in oatmeal, render these unsuited for bread-making. Unleavened breads—not the Jews' biscuit which bears the name—are made by two or three chemical processes or mechanically. Baking powders, as Borwick's, are composed of tartaric acid, bicarbonate of soda, and some rice starch to keep the mixture from being

acted on by the moisture of the air. Mixed with the dough, the ingredients react on one another, evolving carbonic acid, and leaving in the bread a residue of tartrate of soda, which is apt to disturb digestion if such bread be habitually used. A better plan is to mix carbonate of soda with the flour and hydrochloric acid with the water. The product or residue left by this reaction is sodium chloride or common salt, which supersedes the use of salt as such. The only objection to this method is the difficulty felt by unskilled persons in accurately adjusting the proportions of acid and carbonate.[1]

MacDougall's baking powder is made with acid phosphate of lime, and carbonate of potash. Its action is precisely the same as that of Borwick's; but the residue, a phosphate of lime and potash, instead of being injurious, is rather beneficial to the health.

Self-raising flours are flours ready mixed with baking powders in the proper proportions, and so-called custard powders are simply flour and starch coloured with turmeric or anatto, not with eggs.[2]

Neville's bread, besides being baked by steam, is different from all the foregoing, in being raised by the incorporation with the dough of carbonate of ammonia, which is entirely volatilised and dissipated by heat. No residue is left, while the preservation of the sugary matters renders it sweeter, and it is at the same time closer grained than other breads.

Bicarbonate of soda alone is often used by pastrycooks. The heat drives off part of the carbonic acid, leaving a normal carbonate. It is, therefore, unless used very sparingly, open to the same objections as the usual baking powders.

The aerated bread, Dr. Dauglish's patent, is made from

[1] The exact proportions required for neutralisation are 120 grains of bicarbonate of soda and 105 of crystallised tartaric acid, or 133 minims of hydrochloric acid, specific gravity 1·16 to 1 lb. of flour.

[2] The name "custard-powder" is unobjectionable, but to call them "egg-powders" is a positive deception and a fraud.

the finest flour, baked by hot water, and raised by forcing carbonic acid, generated in a separate apparatus, into the dough, which is kneaded by machinery, and the process is so conducted that the conversion of the starch into dextrin, &c., cannot proceed too far. The carbonic acid, made from chalk and sulphuric acid, is supplied at the rate of 20 cubic feet for every 280 lbs. of flour, and about 11 cubic feet are actually incorporated with the dough.

Preservation of Foods.

All moist animal and vegetable matters are prone to putrefaction, but it has been proved conclusively that the association of water, oxygen, and a certain degree of warmth is not alone sufficient, although necessary, for the process, which depends essentially on the action of certain bacteria (*Bacillus subtilis* and others), everywhere present in the air; and that if these be absolutely excluded, the most perishable liquids, as milk, blood, urine, drawn direct from the body, will remain for an indefinite time unchanged.

A host of chemical reagents have also the property of destroying or preventing the development of the germs, but the number of these available for the preservation of food is obviously limited by considerations of wholesomeness and taste.

The various methods employed may be referred to one or more of the following :—

1. Exclusion of aerial germs.
2. Desiccation or withdrawal of water.
3. Addition of germicide reagents.
4. Extremes of heat or cold.

1. Exclusion of Air alone is exemplified in the bottling of wines and beers, and the closure of flasks by a wad of

cotton wool, or covering the surface of a liquid, as wine, by a film of oil, and coating eggs with gum.

Since, however, the substances to be thus preserved are, eggs excepted, already charged with the germs, it is necessary to destroy the vitality of these before sealing the vessels containing them. Thus are preserved the fruits, green peas, &c., put into bottles of water immersed in boiling water, and corked while in a state of ebullition, the unsweetened condensed milks, and American canned meats, fish, fruits, vegetables, &c.

2. Desiccation, natural in the case of ripe seeds, is practised simply in the sun-dried beef which forms the staple food of the Indians of the Pampas, &c.; in potatoes sliced and dried, other dried vegetables, and in the case of dried fruits, as raisins, figs, dates, plums, and apples, aided by the sugar present in the fruits, a natural combination of this with the next.

3. The Addition of Reagents.—The simplest examples of this method are seen in the preservation of fruits and vegetables in spirits and in vinegar, although in the former the alcohol also withdraws water from the tissues. With preliminary boiling in the case of fish, &c., preserved in oil, of sweetened condensed milk, of jams and preserves, in which the excess of sugar prevents putrefaction and fermentation; and in the stability of strongly alcoholic and sweet wines. In smoked meats, &c., hams, salmon, &c., desiccation is combined with impregnation of the flesh with the tarry products of combustion of peat, coal, or the dry distillation of wood.

In salting we have the presence of salt with the abstraction of water by osmosis into the brine. But it must be observed that the inferiority of salt to fresh meat consists, not only in the hardening of the tissues and the addition of an excess of salt, but in the soaking out into the brine of the soluble albumins, and of the potash salts of the meat. Salt meat is therefore not merely indigestible, but has been deprived of much of its nutriment

and dietetic value. Dr. Parkes, however, observed that the soluble albumins and "extractives" might and ought to be recovered from the brine by dialysis. They will not pass through an animal membrane, whereas the salt will, and thus the brine, if placed in a dialyser over pure water, parts with the salt, leaving a rich broth, which should be added to the meat. This should, previously to boiling, be steeped in water, when much of the salt dissolves out, and then be boiled in the extract obtained as already indicated.

In salting beef, &c., a certain proportion of nitrate of potash—saltpetre—is added to the salt to give a red colour to the meat.

Other reagents are less commonly employed, or have at least been proposed, as sulphurous acid, sulphites, boric acid, "formalin," and salicylic acid. The last is used to an unjustifiable extent in France for the preservation of all kinds of food, especially spurious wines. Boric acid is comparatively harmless, and may be useful for the preservation of milk, fish, &c., in hot weather. It is largely used for preserving milk, cream, and butter, as recently is formalin. They are however by no means powerful antiseptics, and their presence unless stated should be deemed an adulteration.

Essential oils, spices, &c., have a certain antiseptic power. They entered largely into the ancient formulæ for embalming, and are now used along with salt, smoke products, &c., in preserving animal foods, as sausages, potted meats, spiced beef, brawn, &c., for short periods. One must not forget that their pungent and aromatic taste may be employed to mask incipient putrescence. Thus unwholesome sausages are always highly spiced.

Cold, if sufficiently intense, prevents putrefaction. Thus fish are sent by road or rail and kept for several days packed in ice. In country houses in Russia, Sweden, and Canada, it is usual to lay in a stock of meat for the winter and to keep it in a frozen state.

It is an important fact that if the freezing process be not begun until after *rigor mortis* has set in, putrefaction commences

very shortly after thawing, and proceeds rapidly. Such meat therefore must be eaten within a couple of days of thawing. If on the other hand, it be frozen immediately after being killed, the phenomena of *rigor mortis*, &c., are postponed until after thawing, when it exhibits no greater tendency to putrefaction than does fresh killed meat. The New Zealand mutton, "chilled" by cold currents produced by the expansion of previously compressed air from the hour in which it was slaughtered until it leaves the market for the shops, preserves its natural condition and flavour unimpaired, which it did not when ice was used.

If putrefaction have already begun, freezing will arrest or suspend it, and even greatly conceal the odour. This is often the case with fish, the condition of which is not recognised until it is cooked.

Heat is the most powerful means of destroying low forms of life, and is therefore, as we have seen, very generally employed to sterilise a liquid or moist organic solid, before hermetically sealing it so as to prevent further ingress of germs. But it cannot for obvious reasons be continuously employed. Repeated sterilisations are practised by housewives who boil again soups, &c., which they wish to keep sweet for several days.

Calculation of Dietaries

While a man has a free choice as to the quantity and quality of his food, natural instinct and appetite will mostly guide him aright; but when as in schools, asylums, armies, and ships, the duty devolves on a director or board of management, the responsibility is great, and the selection of the various articles of food and the determination of the quantity of each demands considerable judgment and a knowledge of their proximate composition, *i.e.*, the percentage of albumin, fat, and carbohydrates in each, and of the several quantities required by each individual under particular conditions of age, work, &c., especially when for economic or other reasons the number of these articles of food is limited. A diet may be ample in quantity, but if one of the food-stuffs be in insufficient amount the health will seriously suffer. This was illustrated in a striking manner in the Duke of York's School for the children of soldiers, where,

while the boys were allowed only $2\frac{1}{4}$ oz. of albumin, 1·9 of fat and 12·8 of carbohydrates, a large proportion were always having cod-liver oil, and a number were sent every year to Netley for change of air (?). Dr. Crerar, by a small change in the diet, raised the allowance to 2·8 albumin, 2·7 of fat, and 13·3 of carbohydrates, with a marked improvement in the boys' health, and the practical abolition of the cod-liver oil list. Again in an Indian famine it was found that men on a purely rice diet died nearly as fast as those absolutely starving; when a ration of pulse was added to furnish the albumin matters improved, but so long as the dietary was no better than what they had been used to, they still lost flesh and strength, for the simple reason that on the relief works a greater amount of labour was exacted from them than they had voluntarily exercised on their native fields, and the same results have been observed in the Indian prisons.

The calculation is effected thus—Having determined on the amount of each of the food-stuffs required for the given case, and having before one the percentages of albumin, fat, and carbohydrates in each of the articles of food included in the dietary under consideration, a series of simultaneous equations, representing the albumin, fat and carbohydrates is constructed by stating on one side the percentages of the food-stuff in each article of food, indicating these by the letters x, y, z, &c., and on the other the amount of the food-stuff it is desired to give. The equations are then solved in the usual way. Thus, supposing a labourer to be confined to a diet of oatmeal porridge and milk only, and that he is to have the full allowance of 5 oz. of albumin, 3 oz. of fat, and 15 oz. of carbohydrates, to determine how much of these foods must be supplied daily in order to attain the desired result, we proceed as follows:—

Including the water and salts, the composition of these foods is—

	Water.	Albumin.	Fat.	Carbohyd.	Salts.
Oatmeal (x)	19	12	6	60	3
Milk (y) .	87·3	4	3	5	0·7

Then, neglecting the water and salts—

$$\text{(1)}\ \frac{12x + 4y}{100} = 5 \text{ oz. (for the albumin.)}$$

$$\text{(2)}\ \frac{6x + 3y}{100} = 3 \text{ oz. (for the fat.)}$$

$$\text{(3)}\ \frac{60x + 5y}{100} = 15 \text{ oz. (for the carbohydrates.)}$$

Solving these equations.

$$x \text{ (oatmeal)} = 20 \text{ oz. or } 1\tfrac{1}{4} \text{ lb.}$$
$$y \text{ (milk)} = 60 \text{ oz. or } 3 \text{ pints.}$$

The salts may be calculated thus—

$$\left.\begin{array}{l}\text{Oatmeal } 3\%\text{; } 20 \times 0{\cdot}03 = 0{\cdot}60 \\ \text{Milk } 0{\cdot}7\%\text{; } 60 \times 0{\cdot}007 = 0{\cdot}42\end{array}\right\} 1{\cdot}02$$

Taking the composition of the more important food-stuffs, as follows :—Cooked meat, albumin 35 per cent., fat 7·5 per cent.; bread, albumin 8 per cent., carbohydrates 50 per cent. ; potatoes, carbohydrates 22·5 per cent. ; poor cheese, albumin 30 per cent., fat 10 per cent. ; bacon, albumin 10 per cent., fat 70 per cent. ; butter, fat 80 per cent. ; oatmeal, albumin 12·5 per cent., fat 5 per cent., carbohydrates 65 per cent. ; milk, albumin 4 per cent., fat 3 per cent., carbohydrates 4·5 per cent. ; and beer, carbohydrates 5 per cent.—a man would obtain the undermentioned weights of each food-stuff in such a diet as—

	Albumin.	Fat.	Carbohydrates
½ lb. = 8 oz. cooked meat	2·8	0·6	...
1½ lb. = 24 oz. bread	1·9	...	12·0
½ lb. = 8 oz. potatoes	...	...	1·8
2 oz. cheese	0·6	0·2	...
2 oz. bacon	0·2	1·4	...
1 oz. butter	...	0·8	...
½ pint = 10 oz. milk	0·4	0·3	0·4
1 pint = 20 oz. beer	...	...	1·0
	5·9	3·3	15·2

This is a fair example of well-arranged mixed diet. A man of great muscular development might well have ¼ lb. more meat, and more laborious work would call for an increase also of the non-nitrogenous part, say another ½ lb. of bread and some more fat. But any uniform diet becomes wearisome, and it is better even to take an excess of nitrogenous food one day and of carbohydrates on another, than to want change and variety. Thus the above diet might be varied by substituting oatmeal porridge for bacon, suet and flour puddings, beans and bacon, &c., for one or other constituent. Most working men take too little fat and some too much meat, unaware that carbohydrates

and fat, *i.e.*, bread and butter, are the best sources of energy. Lastly, a number of green vegetables, fruits, &c., are desirable additions to any dietary.

We have hitherto assumed that the whole of the food ingested is utilised, but as a matter of fact this is far from being the case, and as we remarked in respect of white and brown bread, the coarser the food the more is wasted passing away by the bowel. The finest are consequently often the cheapest in the end. Well-cooked tender meat, fats, especially butter, and the finer starches are utilised to a very great extent; badly cooked, *i.e.*, hard-boiled meat, imperfectly cooked and coarse meals, as oatmeal, pulse, coarse bread, and the cellulin of vegetable tissues, on the other hand, escape digestion more or less. Though the sensation of fulness produced by such food is often mistaken for support, it seems that a diet which left no residue would be undesirable. A certain degree of irritation of the intestinal mucous membrane by indigestible matters appears necessary for the due activity of the peristaltic movements, and highly concentrated and soluble foods are apt from their deficiency in this respect to induce constipation. If, however, the undigested matters be in such quantity as to undergo putrefactive and fermentive changes with evolution of fœtid gases and fatty acids, intestinal catarrh is the inevitable result. The relative utilisation of foods must be kept in view in calculating diets. Beans, for example, are often lauded, especially by vegetarians, as being superior to meat in nutritive value. But they can be fairly compared only in the state in which they are eaten, when meat has lost 20 per cent. of its water, while beans and oatmeal (as porridge) have taken up many times their weight. Again, while 80 per cent. of animal albumin is digested, not more than 46 per cent. on an average of vegetable albumins is so, and still less of some, as the legumin of beans. Twice as much therefore must be taken as of meat, and the excess is apt to disagree with any but the strongest stomachs. It will thus be seen that chemical composition and market price are not alone sufficient data on which to found a comparison as to the economy of several dietaries. But even as regards the relative proportions and actual quantities of the food-stuffs, very few dietaries fixed by regulations, as those of armies, navies, prisons, &c., will be found quite satisfactory. Tables purporting to show the proximate composition of various articles of food do not give a true notion of their nutritive qualities, unless one knows what proportion of their several constituents is utilised in the organism, and what passes away unabsorbed, with the fæces, and is therefore lost. This has been ascertained by Prof. Gruber of Gratz

for a few of the most important and typical forms of food, who gives as the means—

	Total dry substances.	Albumin.	Fat.	Carbo-hydrates.
	In one hundred parts of each there remain unabsorbed—			
ANIMAL FOOD—				
Lean meat	4·7	2·5		
Eggs	5·2	2·9	5·0	
Milk	8·1	6·75	5·2	
Cheeses	6·4	3·3	5·2	
Fats	8	...	12·7	
VEGETABLE FOODS—				
Maize	6·7	15·5	17·5	3·2
Pease	14·5	27·8	...	7·0
White wheaten bread .	4·65	18·18	5·7	1·2
Brown ditto	12·2	30·5	...	7·4
Black or rye bread . .	15·0	32·0	...	10·9
Rice	4·1	20·4	7·1	·9
Potatoes	9·4	32·2	3·7	7·6
Carrots	20·7	39·0	6·4	18·2
Cabbages	14·9	18·5	6·1	15·4

The amount of food and food-stuffs required to maintain the *status quo* or equilibrum of the body, or even to condition an increase of weight, is, however, directly dependent on the state of nutrition of the individual at the time. Thus, to take an extreme example, a hospital diet may appear, when compared with our standard of 5 oz. albumin, 3 oz. fat, and 15 oz. of carbohydrates, insufficient for mere subsistence, and yet it is found in practice that patients will gain weight upon it. So, too, the aged will maintain health and comparative vigour on an amount of food which would be starvation to a young adult, whose usual diet neither the hospital patient nor the inmate of an asylum could duly assimilate.

Even young persons or adults who have long existed on an insufficient diet must be gradually accustomed to a better, or they are sure to suffer from derangements of digestion.

In infancy the diet is of the utmost importance, the future health of the individual being often irrevocably determined thereby. For the first six or eight months it should consist of breast milk, or in default of that, of cows' milk and water in

the proportions of 1:1 or 1:2, and gradually strengthened till it reaches 2:1 or 3:1. The diluted cows' milk should be sweetened with fine white sugar, or better still, milk sugar, which may be obtained of any chemist, and the addition of barley water or *strained* gruel is often an improvement. Condensed milks of the best brands (the Anglo-Swiss, or Nestlé's) are often more easily digested by infants, especially those under six months of age, than is fresh cows' milk. They should be mixed with water in the proportion of one part to twelve, though as the child grows older and stronger, more of the milk must be used. The milk should be mixed fresh for each bottle. The sweeping condemnation of condensed milk, in which some medical men have indulged, is not justified by experience, though much judgment is required to adapt the strength to the digestive powers of the individual infant, so that it shall not suffer from starvation or repletion. The advantage of having it always fresh by day and night is great, and the chief objection is that it frequently tends to induce constipation, or excessive fattening.

In Löfflund's "cream milk" we have a pure, *unsweetened*, condensed milk, which, when duly diluted, is identical with the product of the cow. There are others in the market, both Swiss and Bavarian equally good.

The only artificial food that can safely be given to infants under eight months is Mellin's, in which the conversion of the starch into saccharine bodies is complete.

The chief drawback attending the use of fresh cows' milk even when diluted and sweetened, is the bulk and toughness of the coagulum formed by the casein in the stomach. This difficulty may be overcome by peptonising, or predigestion, which is effected by adding to the milk, previously diluted, Benger's liquor pancreaticus, one or two teaspoonfuls to the pint, with a pinch of carbonate of soda, or more conveniently one of Fairchild's peptonising powders, and allowing the jug of milk to stand in a basin of hot water for about 20 minutes. It should then be boiled for three or four minutes in order to arrest further change, for if the artificial digestion be carried too far the milk acquires a bitter taste.

To obtain the maximum of albumin with the minimum of casein, and the proper proportions of fat and sugar, the milk in Gaertner's process is separated by slow centrifugalisation into a richer and a poorer part; more milk sugar and water are added to the former, and the result is the nearest approximation possible to human milk. Welfords and others attain the same end though by different means.

Asses' milk was formerly in high repute, and its recently proved superiority to that of the cow, for the first six or eight weeks of life, shows that the ratio of albumin to casein, in which it resembles human milk, is of greater importance at that age than the amount of fat, in which it is deficient, though this may be supplied by a small addition of cream.

Whatever the milk it should be always fresh and sweet, and the bottles kept scrupulously clean. The infant should never go to sleep with the bottle in its mouth, but be taught from the first to take its fill, and then to sleep till it wakes hungry. The quantity given at each meal should be measured and not left to chance. Beginning with 1½ oz. it should be increased to 2 oz. at one month, 4 oz. at two, and 6 oz. at four months and upwards. Bottles should not be fitted with tubes, which are always foul inside, and those graduated for measuring and with a thermometer embedded in the glass for regulating the temperature, are most convenient. The intervals should be at first two to three hours, then three to four by day, and four to six at night. No starchy food should be given till the eruption of six or eight teeth shows that the salivary glands are acquiring the power of secreting ptyalin, which has the property of acting on starch. Solid food should not be given until the first molars are cut. At first farinaceous food should be given in the form of biscuit powder, nursery biscuits, or even bread and milk rather than the unmodified starches of arrowroot and oatmeal. If these are given too soon the child will probably be rickety or scrofulous. If a mother cannot nurse a child entirely, and few women in towns can, a good rule is breast milk for three months, breast and bottle for three to six more, then bottle milk and food for another six, after which the bottle may be given together with more solid food such as bread and milk, light puddings, &c. Gravy and beef tea may be given from six months, and eggs lightly boiled soon after. All "foods" except Mellin's should as a rule be eschewed for six to nine months, and milk should still be the staple food for another year. Tea and coffee should not be allowed for at least six years, and then only with plenty of milk. Meat may be given after two years, but if the child will take plenty of milk it is not necessary even then. Potatoes, unless very mealy, are by no means to be recommended for two years as least. Milk well suits the periods of rapid growth and of convalescence, which involve also rapid tissue change. Cooked, dried, and *fresh* ripe fruits may be freely allowed after the second year. Indigestible food, especially grocers' currants,

is a common cause of convulsions, erroneously ascribed to teething.

Nursing mothers should live well, *i.e.* take plenty of nourishment, but no more malt liquor than they would at other times, if, indeed, they take any. Beer increases the quantity of milk but not the quality, the watery part but not the solids. They can take no better drink than milk or thin milk gruel, as much as they like.

Growing lads can assimilate both relatively and absolutely a larger quantity of meat than adults, and in fact need it, whereas in after-life a much less amount than is commonly indulged in by well-to-do people and highly paid labourers, as navvies, would be found not only sufficient but advantageous, more fat and carbohydrates being taken. Outdoor exercise enables a man to dispose of more meat than his organism really requires, but with sedentary occupations and brain work such excess leads to gout or derangements of digestion and elimination. In training meat may be taken in larger quantities, and watery or indigestible food and saccharine foods and drinks should be avoided, but the extreme and unnatural diets formerly prescribed are to be deprecated.

Bantingism, so called, is an attempt to reduce excessive corpulency or accumulation of fat by availing one's self of the property possessed by albuminates of favouring rapid metabolism or disintegration of tissue, and avoiding that of the non-nitrogenous food-stuffs, especially the carbohydrates, of saving tissue, and of leading to the storing up of fat in the organism. Founded on well-known physiological principles, it must, however, be employed with caution.

Vegetarianism is based on the fact that the vegetable kingdom furnishes examples of all the three food-stuffs, but in practice very few, if any, of its professors are strictly consistent, and partaking freely of milk, butter, eggs, and cheese, they, in fact, simply abstain from flesh.

Glutin and legumin are quite capable of taking the place of animal albumins (though the vegetarian does not refuse caseine, fluid or coagulated), but as we said before, the extent to which any food-stuff can be utilised is an important consideration, and the animal albumins and fats are far more completely assimilated, and are therefore more economical than the vegetable. Legumin, vaunted as the equivalent of meat fibrin, is especially hard of digestion ; the ingestion of a sufficiency of glutin which is more digestible involves that of an excessive amount of starch, and if a vegetarian were true to his principles, he ought to

confine himself to almost the only palatable vegetable fats, olive and a few other oils.

The relative digestibility of animal and vegetable food stuffs is well shown in the following table from F. Hoffmann :—

Weight of Food.	Vegetable Diet.		Animal Diet.	
	Digested.	Not Digested.	Digested.	Not Digested.
Of 100 parts of Solids . .	75·5	24·5	89·9	10·1
Do. Albumins	46·6	53·4	81·2	18·8
Do. Animal Fat and Vegetable Carbo-hydrates . . .	90·3	9·7	96·9	3·1

The large proportion of vegetable albumins which remains undigested leads to putrefactive changes in the bowel and disturbances of digestion, even in races as the Hindoos, who have been inured to such diet by long habit, and much more in those whose digestive organs have been accustomed to a mixed and selective dietary.

Summary of Chapter III

Cooking is intended to render foods more digestible and more tender, by the action of heat with or without water. It coagulates albumen, dissolves gelatine, bursts starch granules and softens celluline. Meat, whether roasted or boiled, loses 20 to 25 per cent. of its weight in water and fat ; whereas vegetables, seeds and farinaceous foods take up much water ; potatoes and rice should be steamed, or the superfluous water driven off. Eggs are not more digestible even if lightly boiled, and indigestible if hard boiled.

Soups and beef tea contain the serum albumen in flocculent coagula, gelatine, &c., farina, &c., being added to soups. The nutritive value of beef-tea is greatly overrated. Meat juices have little, and the so-called extracts have no value as foods, though some as stimulants. **Extracts** consist chiefly of waste and effete products of metabolism.

Bread. In the process of baking the starch is considerably modified, and the dough which, owing to the presence of gluten, is more tenacious than mere paste, is made to assume a spongy

texture by being permeated with bubbles of CO^2, further expanded by heat. The gas is evolved through the fermentation of the sugar formed in the dough when yeast is used, or the reaction of an acid on a carbonate in baking powders, or the action of heat on sodium bicarbonate or on ammonium carbonate mixed with the flour, or lastly, in the so-called aërated bread, is forced into it from without. Good bread should not contain more than 34 per cent. of water, but 40 per cent. is often present. Wheat and rye only are available for bread making, though rice may be added. The albumen is from 6 to 9·5 per cent., the starch 50 to 55 per cent. The alleged higher nutritive value of coarse and brown flours based on chemical analysis is illusory, being more than counterbalanced by their less digestibility.

Foods are preserved by (1) exclusion of aërial germs after sterilisation by heat; (2), dessication; (3), the addition of germicidal reagents, or (4) sustained exposure to heat or cold, *i.e.*, boiling or freezing.

Calculation of dietaries. Since health cannot be maintained or the body kept at the state of vigour required for the particular demands made on it without the requisite quantities and proportions of the three foodstuffs, albumens, fats, and carbohydrates, and no single article of food fulfils these conditions, the quantities of the several constituents of the dietary must be so adjusted as to give the desired aggregate result. This is done by working out three simultaneous equations of as many dimensions as there are foods containing one or more of the three food stuffs. But allowance must be made for waste, a greater or less proportion of each passing away undigested, and in comparing the relative nutritive value of foods they must be compared in the states in which they are eaten, for while the percentage of water in raw meat is 70, and in pulse and oatmeal 10 to 15, that in cooked meat is about 56, but in porridge or brose nearer 85. And again, while but 2·5 per cent. of the albumen, with 5 per cent. of the total dry matter of meat is lost in digestion, 28 per cent. of the albumen with 15 per cent. of the total nutriment of peas passes away with the fæces

Milk is the food for infants, though neither fresh nor condensed cow's milk is fully equivalent to breast milk; farinaceous foods are ill adapted to their digestion during the first year of life, and the use of starchy foods is a fertile source of diseases of malnutrition.

QUESTIONS ON CHAPTER III

1. What are the effects of (*a*) boiling and of (*b*) roasting on meat, and what precautions should be observed in each process? What is frying, and how is it best done? What changes take place during boiling in (*a*) potatoes and (*b*) greens? In what does the art of boiling potatoes and rice consist?

2. Under what conditions only can meat, oatmeal, and beans be fairly compared as regards their relative nutritive value? and what further abatements must be made in respect of the last two?

3. Describe the process of making bread. How does "aërated" differ from home-made or baker's bread? 1900, E

4. Compare the action of baking powder and "self-raising" flour with the processes of fermentation and aëration.

5. Mention the constituents common to tea and coffee, and those peculiar to each. What are their respective actions on the system, and how do these and their physical properties bear on the modes of preparing the beverages?

6. State what you know of the nutritive value of home-made beef tea, and of the chief preparations, extracts, juices, peptones, &c., in the market, from the composition. Of what do the so-called "extractives" consist, and is it possible to concentrate the nutriment of many pounds of meat into as many ounces?

7. What do you know of the digestion of starch in the human body? What is the action of diastase? Describe the artificial digestion of milk and farinacea.

8. What are condensed milks? Give the percentage composition of the sweetened and unsweetened. Compare them with "sterilised" milks. How much raw milk is represented by one volume of condensed?

9. What is meant by subsistence and average diets? What changes, quantitative and qualitative, are indicated when the work required is increased? What is the effect of hard work with insufficient food? and conversely of an excess of (*a*) proteids and (*b*) of carbohydrates over the necessities of work done?

10. Under what conditions, internal and external, can health be best maintained on a diet little better than a "subsistence"? Explain why a convalescent will gain weight on a diet under which another person, or he at another time, would lose? Also

why, with total deprivation of food, life can be far longer maintained with water than without.

11. What are the advantages of cooking by gas? What conditions should a gas-cooking oven fulfil? 1888, E.

12. Explain the essential object of cooking, and the changes that meat, bread (dough), and vegetables respectively undergo when baked. 1893, E.

13. What changes are effected in, and is any loss suffered by, meat in the process of salting? Is there any value in the brine, and if so can it be utilised, and how?

14. Sketch a purely vegetable diet which would supply the several proximate aliments in sufficient quantity for a standard diet in ordinary work. Show the amounts of N and C in the diet. 1893, H.

15. Discuss Vegetarianism strictly so-called, and that admitting eggs, milk, and milk products. Compare these with the purely meat diets of the Gauchos of South America, &c.

16. What are the principles on which the dietetic treatment of obesity, "Banting," Oertel's, &c., is based? And what diet and habits would you advise for fat production?

17. Rickets and scurvy are called dietetic diseases. To what special errors or deficiencies is each to be chiefly ascribed? What other causes, if any, conduce to each disease? How may each be prevented?

18. How do wheat, oat, maize and rice meal differ as regards their suitability for bread making? Why is rice often mixed with wheat flour?

19. Compare brown, whole meal, and fine flour breads, biscuits and pastry as regards their making and their dietetic value.

20. Explain the calculation of dietaries by simultaneous equations, illustrating it by examples of work and fatigue diets suitable for troops on active service, selected from among the following articles, constituted as under:—

	Alb. %	Fat %	Carbohyd. %
Oatmeal	12·0	5·0	64·0
Bread	8·0	1·0	50·0
Biscuit	16·0	1·0	72·0
Pea flour	22·0	1·5	58·0
Cocoa (raw)	15·0	48·0	25·0
Raw beef	20·5	1·5	
Salt beef	30·0	1·5	
Salt pork	26·0	8·0	
Cheese	28·0	24·0	
Condensed milk (sweet)	10·5	9·5	50·0

Water, woody-fibre and salts neglected.

21. Classify the several means used for preserving foods, giving examples of each, and their effects, if any, on the digestibility and nutritive value.

22. What is the dietetic value of fruits? and which contain appreciable proportions of food stuffs?

23. What is the general composition of nuts? Discuss their value as food.

24. What "preservatives" are most often added to milk by petty dealers, and to what extent do they fulfil or fail to fulfil their purpose?

25. Classify the different kinds of cheeses, according to the means employed for coagulating the casein and the amount and nature of the fatty constituents.

26. What is the essential cause of the difficulty attending the rearing of infants on cows' milk, and how may it be to some extent obviated?

27. What objection is incident to "infants' foods" (so called) in general, and are there any against which it cannot be urged?

28. Discuss the advantages and disadvantages of condensed milks (sweetened) as food for infants.

CHAPTER IV

Sound and Unsound Meat

The flesh of animals affected by disease, whether such disease were the cause of death, or the animal were slaughtered while so suffering, may be simply deteriorated in quality, or be rendered unwholesome, or even totally unfit for human consumption. So, too, with regard to commencing putrefactive changes in meat previously sound.

Meat should be inspected within twenty-four hours of slaughtering, but though exposure to air and evaporation somewhat alter its appearance, a fair opinion of its quality may be formed for some time longer.

A due proportion of fat indicates, as a rule, a good state of nutrition, but the excessive amount seen in fatted beasts is objectionable, not only as being of less nutritive value than the muscle which it displaces, but as

evidence of fatty degeneration which is not health. The colour of the fat depends partly on the age and sex, but chiefly on the food of the animal. It should, however, not be too yellow, watery, or soft, and certainly not specked with blood.

The muscle should be firm and elastic, of uniform consistence and colour throughout, slightly marbled by lines of fat through its substance, and yielding a little reddish juice on compression. The odour, especially on section, should be fresh and by no means unpleasant. The flesh of young animals is paler and moister than that of old, but the colour, though it varies with age and with the part of the body, should never be livid or deep purple.

The first sign of commencing putrefaction is a change in the smell, which becomes faint, then disagreeable, and at last repulsive. The colour grows paler, and later greenish, while the interior of the muscle softens in parts. A knife plunged for its whole length into the meat will detect any change of consistence, and its smell when withdrawn gives a clue to the state of the interior.

Disease is generally indicated by a watery, sodden, inelastic muscle, the fat being deficient in wasting, and reddish yellow or blood-stained in inflammatory, diseases.

The liver, spleen, &c., and the marrow, are sooner and more affected, both by disease and by putrefaction, than other parts.

Effects of decomposing food vary with the individual and the kind of food. "Game" is eaten with impunity by all when *post mortem* changes are far advanced, and mutton under some circumstances may be allowed to become high. Beef soon becomes unwholesome, and pork still earlier, while the slightest trace of change in fish, crustacea, and shell-fish, renders them well nigh poisonous.

Yet in every climate are found races who have, not always compelled by circumstances, acquired the power of digesting meat or fish in an advanced state of decom-

position. The Eskimo relishes putrid blubber; and Burmese and Siamese employ putrid fish as a condiment.

But among persons unaccustomed to its use putrescent animal food causes severe pain in the stomach and bowels, vomiting, diarrhœa, and probably cramps, due to poisons formed by the bacteria of putrefaction. Evacuation of the stomach and bowels, followed by an opiate, with brandy or other stimulants, if there be alarming depression, gives speedy relief. In mild cases, looseness and colicky pains sometimes persist until the bowels are cleared by a purgative, as castor oil.

Sausages, canned tongues, &c., occasionally give rise to effects more severe than can be explained by mere putridity, and which are caused by intensely poisonous alkaloids produced by certain bacteria.

More rarely the flesh of healthy animals has induced symptoms of poisoning, probably due to their food. Thus many kinds of fish and crustacea, though perfectly fresh, oysters and mussels, and even pork, especially in India, have given rise to serious and fatal disturbance of the digestive organs. A poisonous alkaloid, called tyrotoxin by Prof. Vaughan, who detected it first in cheeses, is formed in milk if agitated without having been previously chilled.

Stale eggs may be detected with unerring certainty by holding each perpendicularly between the finger and thumb before a candle in a dark room and slowly turning it round, rejecting all that show an opaque mass or shadow on one side. Eggs that can pass this test are as "good as new laid."

Diseases of Cattle as Affecting the Fitness of their Flesh for Food

It is not proved that any ill results follow the use of meat from animals killed in the earliest stage of acute inflammations, not fevers, but it would be advisable to let the blood drain completely away. Chronic wasting diseases render the flesh pale and watery. It cooks

badly, causes sickness and diarrhœa, and is prone to early decomposition. As regards acute specific diseases, the evidence is conflicting. In sheep-pox the flesh has a repulsive odour, and causes diarrhœa, vomiting, &c. Acute and contagious pleuro-pneumonia cannot but profoundly alter the character of the flesh, and though it has been eaten with impunity, yet boils and other states of ill-health have been referred, and probably rightly, to its use. So, too, with pig scarlatina, &c. No doubt boiling, or thoroughly roasting, removes much of the danger, but such flesh must be unwholesome, at least to ordinary stomachs.

As to the septic class of diseases, the evidence is more complete. Scotch shepherds do eat "braxy" mutton, but not until it has been steeped in brine for two months, long enough to kill any bacteria. Boiling, too, would destroy a living organism, but it is seldom that the interior of a joint reaches the required temperature. Many deaths, however, have followed the use of the flesh of animals affected with anthrax, &c., and when we consider that the skins and wool are capable of fatally inoculating those who handle them, it is in the highest degree unsafe to trust to cooking to render the flesh innocuous; though there is little doubt but that discordant statements as to the effects may find their explanation in the degree of heat, or other agents, as salt or smoke, to which the meat has been subjected.

The milk of cows suffering from febrile diseases should be avoided, and certainly that of such as have any disease of the udders. Foot-and-mouth disease is directly communicable as such by milk, a fact not only observed but proved by experiment, and may be fatal to infants. Boiling, however, renders such milk harmless, and should always be practised when the disease is prevalent. As to tubercle, the evidence is obviously less satisfactory than with a disease the incubation of which is only four or five days, but there is no doubt as to its communicability, at

least if the milk be used habitually. Primary tuberculosis of the bowels, rare in the adult, is the most frequent form in infants, and while all others have greatly diminished of late years, this alone has increased, as has the use of cow's milk.

Summary as to Diseased Meat

There is no possible objection to the use of the flesh of animals killed by accident or surgical operation ; nor, if the blood be allowed to run off by division of the vessels in the neck, to that of animals dying of apoplexy, choking, or from difficult parturition. The flesh is not necessarily depreciated if the animal were slaughtered on account of impending death from obstruction of the bowels, or when suffering from prolapsus ani, hæmorrhoids, pulmonary or intestinal catarrh, emphysema, and some skin diseases, as pemphigus, herpes, &c.

It is depreciated by tuberculosis or pearl disease in its early stages, by pneumonia, pleurisy, and foot-and-mouth disease however mild, by diarrhœa and diseases of the heart and kidneys, and by the presence of parasites other than tæniæ, although the infected organs may have been removed.

It should be condemned unconditionally in all cases of cattle plague, pleuro-pneumonia, sheep-pox, acute rheumatism, acute specific diseases, as the so called pig-typhoid or swine fever, and blood-poisoning, as erysipelas, black-quarter, &c., anthrax, peritonitis or parametritis, and cysticerci and trichinæ among parasites. But flukes in the liver and cœnuri in the brain demand the destruction of the affected organs only.

Tuberculosis, when it has advanced so far as to cause any appreciable alteration in the nutrition or in the appearance of the flesh, should be deemed ground for its condemnation, but joints that are positively prime need not be rejected because the pleura or lung is slightly affected.

Diseased Corn and Vegetables

In the valley of the Po, in Roumania, and elsewhere, the disease known as Pellagra prevails wherever Indian corn or maize, stored in damp chambers, is used. Volumes have been written on its cause, but Drs. Lombroso in Italy, and Felix of Bucharest, the latest and best authorities, concur in attributing it to a fungus peculiar to that grain.

Acute poisoning has frequently been observed both in man and in the horse after eating bread or biscuit, which, from being made of damp and spoilt flour, has speedily developed moulds as *oïdia*, *aspergilli*, &c. We have less positive information as to the effects on man of diseases of the vegetable kingdom, though the tendency of rotten or over-ripe fruit to cause gastro-intestinal irritation is well known.

The potato disease is produced by a parasitic fungus (*Peronospora infestans*), which permeates the tuber. It is killed by boiling, and the unwholesomeness of diseased potatoes is due rather to the changes effected by it in the starch.

Wheat and other cereals are attacked by several forms of fungi, some of which do not seem to exert any hurtful influence. Smut, a species of Puccinia, gives a bluish colour to the bread and a disagreeable smell. It is said to cause diarrhœa. Ergot (*claviceps purpurea*), chiefly found in rye, is more injurious, its habitual ingestion leading to grave forms of cachexia, convulsions, and gangrene of the extremities, ending in death; and though the ordinary mould of cheese is harmless, the occasional occurrence of poisoning by cheese has been thought to be caused by some other species. The poison is doubtless an alkaloid.

Adulteration of Food

The subject of adulteration of food is a wide one, and the detection of all possible additions to and sophistica-

tions of articles of food and drink demands considerable skill in chemical and microscopical manipulation. We can here afford space only for an enumeration of those of more frequent occurrence, and for indicating the methods, mostly qualitative, for their recognition, which are easily practised.

Adulteration is defined by the Sale of Food and Drugs Act, as the mixing, &c., of any article of food or any drug with any ingredient rendering it injurious to health, or so as to affect injuriously the quality or potency of a drug, to fraudulently increase the bulk, weight, or measure, or to conceal the inferior quality of the same, or in any way to cause that it shall not be of the nature, quality, or substance it professes to be, or which is asked for or expected.

The addition, therefore, of anything which detracts from the value or strength of the article, though such addition may be in itself perfectly innocuous, is adulteration equally with the addition of poisonous matter, *e.g.*, the dilution of milk with water is so, no less than the colouring of sweetmeats with copper or lead. The substitution of potato starch for arrowroot, though they are of equal nutritive value, is tampering with the nature or quality of the article in question ; to colour mustard with turmeric with the aim of concealing its adulteration with wheat flour is an offence ; but the staining of cheese with annatto is not. The shades of colour by which whisky, brandy, and rum, are distinguished from one another, and from gin, are purely conventional and artificial, but legal ; whereas if the basis of the rum were corn or potato instead of molasses spirit, it would be of another quality or nature than that expected by the purchaser. Abstraction of any constituent, as of cream from milk, is a fraud ; but the removal of the fat from cocoa is a legitimate process, since the entire article is not relished by many, and except in form of chocolate the abstraction of a part of the fat is desired by most persons.

The margarine or "filled" cheeses, in which mutton fat is substituted for the butter fat, are obviously more nutritious than other cheeses from which also the natural fat has been removed for making butter, and may well be sold provided it is not pretended that they are "full" cheeses, *i.e.*, cheeses made from unskimmed milk, to which they are, however, little inferior.

But there are several cases or forms of adulteration which the present law fails adequately to meet. The addition of a qualifying epithet is held to exempt that which would otherwise be an adulteration from the penalty it properly deserves. It would be better that the nature of the addition should be plainly stated. Thus while it is punishable to sell as pure coffee, or even as coffee without any qualifying affix, a mixture of chicory and coffee, no action can be taken against the vendors of "French coffee," though seventy five per cent. of the article is chicory, acorns, date-stones, or beans. Again, "prepared" cocoa may consist to the extent of eighty or eighty-five per cent. of starch and brown sugar, and many magistrates refuse to convict because some such addition is implied in the word "prepared." A limit might in these cases be advantageously fixed by law, or the proportions of each ingredient should be distinctly indicated. *Caveat emptor* is a sorry plea when the buyer is ignorant of the tricks of trade. Once more, the addition of alum to bread, with a view to the production of a dry white and spongy bread from flour which has been so damaged that without it the bread would be dark and clammy, is recognised as a fraud; but an excess of water which reduces *pro tanto* the nutritive value of the bread, is, morally though not legally, as much a fraud as short weight; and where the consumer cannot satisfy his needs by using a larger quantity, but must be content with what is served out to him, as is the case with soldiers and the inmates of public institutions, he suffers in body, no less than the independent purchaser does in purse.

Thus, too, a mother may give her infant a pint of milk daily, to which she adds an equal quantity of water, but if the milk be already diluted, the child receives in reality little over half a pint of genuine milk. The injury thus inflicted on the children of the poor is perhaps much greater than is generally supposed.

We will proceed to notice the more prevalent and important adulterations of articles of general and necessary consumption, as bread, milk, butter, cheese, tea, coffee, and cocoa, beer, wines, and spirits, and condiments, with a few of the tests which require but moderate skill and ordinary apparatus.

Flour and Farinacea in General

The proportion of glutin, ash, &c., have an important bearing on the quality of a flour, but do not properly come under the head of adulteration, and for the determination of these we must refer the student to the works of Wynter Blyth and others. The only points to which we can here direct attention are the detection of the several fungi present in damaged flour, the recognition of the various forms of starch by the microscope, and the simple qualitative determination of the presence of alum, the quantitative estimation of which is a matter of no small difficulty even to professional chemists.

Two fungi are of not unfrequent occurrence in flour, viz., bunt and smut. Bunt, called also pepper brand, and botanically *Tilletia caries*, is a very common disease of wheat. It grows within the grain, where its spores form a fine soft and somewhat greasy powder, which, when rubbed, emits a disagreeable odour. Under the microscope they present a characteristic appearance, being large (*i.e.*, from ·0006 to ·0008 of an inch in diameter), round, and reticulated. Smut, called also dust brand, *Ustilago segetum*, seldom attacks wheat, but is common in barley and oats. Its spores are much smaller than those of bunt (being not more than ·0002 of an inch in diameter), and are inodorous. They are circular, nucleated and not reticulated.

Mildew (*Puccinia graminis*).—The ripe sporangia are dark brown club-shaped bodies divided into compartments filled with spores. In an earlier stage of its development it constitutes the red rust.

Penicillium glaucum forms the mould on stale bread, especially frequent when badly baked or containing an excess of moisture. It presents the appearance of beaded tufts in greenish patches, and either itself or through the products of its growth occasionally gives rise to serious symptoms of poisoning. It occurs also on cheese and animal foods.

Ergot (*Oidium abortifaciens*) is most frequently met with in rye, attacking the grain at an early stage of its development, and transforming it into a brown brittle body somewhat resembling a carraway seed about an inch in length, and containing in its cells a peculiar odorous fixed oil instead of starch. The cells are oblong, and not coloured blue by iodine as starch cells are. It is more injurious to health than are bunt and smut, though flour containing much of either of the latter fungi should be condemned as damaged and as probably more or less unwholesome.

Various Forms of Starch Grains

It is very important to be able to recognise under the microscope the various forms of starch cells, since most of the adulterations of flours and farinaceous foods consist in the substitution or admixture of other and cheaper kinds. Thus potato and rice are largely used in place of the more costly starches known as arrowroots, and may under certain circumstances be added to wheaten flour.

Wheat Starch.—The most striking feature is the inequality of size, the largest granules being as much as ·0011, and the smallest not more than ·0001 of an inch in diameter. The larger granules have a central spot or hilum and faintly marked concentric rings, while the smaller are seen under a high power to be distinctly angular.

Barley Starch.—The granules are very similar in size and appearance to those of wheat, but the larger are more irregular in form, and their rings more distinct, while the hila are either round or linear.

Rye Starch presents the same variety in size, but the larger granules are still larger and more flattened ; the hila are stellate.

Oats.—The granules are much smaller than the preceding, and more uniform in size, ·0001 to ·0004 of an inch, polygonal, and only a few of the largest have a hilum.

Rice Starch.—The granules are still smaller, ·0001 to ·0003 of an inch, polygonal, and with almost imperceptible hila.

Potato Starch.—The granules vary greatly in size and form, some being small and circular, but others, and those by which alone it is recognised, large and oyster-shaped, with well-marked concentric rings, a very clear though small hilum at the narrow end, and occcasionally another at the broad end.

These two last, viz., rice and potato starches, are those most frequently employed as adulterants.

Arrowroot.—This name was at first applied to the rhizome of the *maranta arundinacea* from its supposed power of counteracting the effects of poisoned arrows, but is now used to designate almost any kind of fine and pure starch, prepared in such a manner as to be capable of substitution for that of the *maranta*, especially those obtained from the *Curcuma angustifolia*, *Tacca oceanica*, *Canna edulis*, and certain species of *Smilax*.

All these starches may be fairly called arrowroots, but the substitution or admixture of potato, sago, tapioca, &c., must be considered as adulteration.

Arrowroots are sold under a variety of names, as Bermuda, St. Vincent, East Indian, Sierra Leone, &c., but these titles are misleading, being applied indiscriminately to the products of different plants, or to that of the same plants grown in different places. By East Indian arrowroot is generally meant the product of the curcuma, and by West Indian and Bermuda that of the maranta, though this is also cultivated in the East Indies. South Sea arrowroot is mostly the product of the canna. It would be much better that they should be compulsorily distinguished as Maranta, Curcuma, and Tacca arrowroots.

Their microscopic appearances are characteristic.

Maranta.—The granules are more or less oblong or ovate, but many are mussel-shaped or irregular ; the rings are delicate but well defined ; the hila are sometimes round, but most frequently present the appearance of a sharply marked transverse line or slit, by which maranta starch may always be identified without difficulty.

Its behaviour with boiling water differs also from that of other starches, the granules swelling to twenty or thirty times their original size. The markings are effaced, and the contents at once escape, forming a uniform gelatinous mass.

Curcuma.—The granules vary in size, but the larger greatly exceed those of the maranta in magnitude. They are flat, elongated, often gibbous or constricted. The concentric lines form segments only of circles ; and the hila, which are at the narrow end, are very indistinct and often absent.

Canna (called also *Tous les mois*).—The granules somewhat resemble those of the potato, but are very much larger and flat ; the striæ, too, are more numerous, regular, and distinct.

Tacca.—The granules resemble those of sago (which see), but are smaller. They are truncated or wedge-shaped at the end, but appear circular if seen endwise. The rings are indistinct, and the hilum circular or fissured.

Sago is prepared in Sumatra and other islands of the Eastern Archipelago from the pith of several species of palm belonging to the genera *Sagus* and *Saguerus*. It is imported *viâ* Singapore in the form of meal or flour, which is then washed and bleached or granulated. The granules are large, truncated, with wide bases, indistinctly ringed, and with a more or less stellate hilum at the apex. Those of granulated sago are much altered by heat, and their features greatly obscured by the manipulations to which the starch is subjected. A spurious sago is manufactured in Germany from wheat or potato starch.

Tapioca or **Cassava** is obtained from several species of *Manihot*, a genus of Euphorbiaceous plants, natives of Brazil,

one of which yields a bitter poisonous juice, which is washed out in the preparation. The granules resemble those of sago, but are smaller, and often adherent in groups; the hila are distinct, and mostly, but not always, circular.

The granules of all starches obtained from leguminous plants, as peas, beans, and lentils, are uniform, with a longitudinal branching hilum. Their form may be compared to that of coffee beans, and is quite characteristic.

Detection of Alum in Flour and Bread

The quantitative estimation of alum is possible only by means of an elaborate analytical process, but it is easy to determine the presence of the adulteration in either flour or bread by the logwood test, and in flour by shaking it up with chloroform. If a sufficient quantity of the flour to be examined be agitated with chloroform in a large test tube, and then allowed to stand for some time, the alum being insoluble in that liquid is deposited at the bottom of the tube, while the flour, from its lesser specific gravity, rises to the top. The sediment may then be examined under the microscope, and also submitted to the ordinary tests. It should consist only of siliceous and calcareous matter from the millstone, and mineral matter of various kinds.

For the logwood test 5 grams of the chips are exhausted by steeping in 100 ccs. of strong alcohol, and 15 grams of pure carbonate of ammonia are dissolved in 100 ccs. of distilled water.

In the case of flour a small quantity, say 5 grams, is made into a thick paste with 5 ccs. of water; 1cc. of the logwood tincture is added, quickly followed by the same quantity of the ammonia solution. If the flour be pure the colour will be pink, soon fading to a dirty brown; if alum be present it will be lavender or blue, the bluish hue increasing in depth with the amount of alum.

To apply the test to bread a quantity of the crumb is broken up in distilled water, and allowed to stand for twelve hours. The water is then strained off, and the test solutions added, or a slip of pure gelatin having been introduced at first is withdrawn at the expiration of the twelve hours and dissolved in the mixed test solutions, which will exhibit a pink or blue coloration according as alum is absent or present. This test is not absolutely distinctive of alum since carbonate of magnesia will produce the same effects, but as alum is the far more probable adulterant, it affords at the least strong presumptive evidence.

Milk

The fraudulent manipulations to which milk is subjected consist merely in skimming or the removal of a part of the cream, and the addition of water, with perhaps salt or sugar, also of preservatives, usually boric acid, and occasionally salicylic, but of late formic aldehyd, or "formalin," has been extensively used.

The petty dealers who supply the poor are the largest employers of preservatives which enable them to carry over their surplus milk to the following day.

Milk may be described as water in which are dissolved sugar, casein, and salts, and in which a quantity of fat is suspended in a state of minute division. Now, since sugar, &c., are heavier than water, their presence tends to raise the specific gravity of the milk, while fat being lighter than water (milk fat specific gravity = ·9) tends to lower it. The actual specific gravity of the milk is the resultant or balance of the two opposing factors. Given a certain percentage of solids not fat, and in consequence a certain specific gravity above that of water, any addition of fat can only lower it; and conversely, given a fluid containing both solids not fat, and fat, the withdrawal of the latter will raise it.

In other words, the specific gravity of milk is always higher than that of water, in virtue of its containing casein, sugar, and salts, but how much higher depends on the less or greater amount of cream; skimmed milk having the highest possible specific gravity, as containing the least amount of fat, and the effect of skimming being always to raise *pro tanto* the specific gravity of what is left.

Watering any milk, whole or skimmed, lowers the specific gravity, since it reduces the percentage of solids not fat, which is just the reverse of skimming.

If we have a milk with a specific gravity of 1030, we may, by skimming, raise its specific gravity to 1032, and then by diluting it with water, reduce it again, *i.e.*, the entire milk is rendered heavier by the removal of the cream, and that which has been twice impoverished has the same specific gravity as it had when pure.

It will be thus easy to imagine the erroneous conclusions to which one may be led by trusting to the evidence of the lactometer alone. As part of a complete examination of milk, and taken together with other evidences, the chemist derives much information from the specific gravity, but in the hands of the ordinary dealer and consumer the lactometer can scarcely fail to mislead.

A low specific gravity is an indication of an absolute or relative excess of the fat or of an absolute deficiency of all solids, and a high one of an absolute or a relative excess of solids not fat; thus a low reading on the lactometer may mean that the milk has been watered or is rich in cream, and a high reading that it has naturally but little fat, or that it has been skimmed.

Indeed, at one public institution the managers used to permit no milk to enter which did not show a specific gravity marked by an M on their own lactometer, but this was fixed so high that the milk purveyor was compelled to remove some of the cream in order to pass his milk !

From these remarks it will be seen that there can be no ready and easy method of detecting the dilution or fraudulent impoverishment of any particular sample of milk. The composition of milk, pure or adulterated, is entirely a question of degree. The milk of one cow may be so rich in every way as to bear dilution to the extent of 10 or 15 per cent. without becoming poorer than that of others ; or it may be able to spare a part of its cream and still come within the description of a fairly rich average milk. Even complete analysis cannot distinguish between added and original water, and the law can only fix a standard of the proportion of solids, and condemn such milks as fall much below.

That usually adopted by our analysts is 87·5 per cent. water, and 12·5 total solids = 9·3 solids not fat, and 3·2 fat.

Stall-fed town cows give occasionally a much higher proportion of fat to the other solids, even approaching the following: water 86 per cent., solids not fat 10 per cent., fat 4 per cent. Again, the fore milk, or that which is first drawn from the udder, is very deficient in fat, and differs little from skim milk, while the strippings or last drawn is so rich in fat that it is occasionally milked apart and sold as cream. This difference is observed even in the milk of the human female. Indeed, dairymen charged with adding water to their milk have been known to draw the first half-pint or so of fore-milk in the presence of a magistrate and offer it for analysis in proof of their innocence, knowing that it would be at least as poor as that in respect of which they had been justly convicted.

But the fact that such milk or even the whole of the milk of certain cows as those that have long since calved, and others, may be poorer in all its constituents than is required by an arbitrary standard, is no argument against fixing one. If any cow yield milk of extraordinary poverty no man has a right to pass it as pure and good. He may not have added water, but so far as the consumer, perhaps a nurse child, is concerned, it is the same as if he had.

Many milk analysts of great experience, as Dr. Vieth, Mr. Otto Hehner, and Dr. Bell, consider the standard of the Society of Public Analysts pitched too high as regards the solids not fat, and would fix a minimum of 8·5. The fat on the other hand generally exceeds 3·2, indeed in good samples is over 4 per cent.

Much difficulty in obtaining convictions would be saved by a legal definition of milk as the "mammary secretion of the cow, containing at least 8·5 per cent. of solids not fat, and 3 per cent. of fat;" anything under 9 per cent. of solids not fat, and 4 per cent. of fat, being deemed to be of the inferior quality; and any falling below the minimum should be held not to be "of the nature, quality, or substance" of the article purported to be sold. No real hardship would be inflicted, for whatever differences there may be in the milk of individual cows, they are lost when it is mixed with that of others above and below the average. Except in very cold weather, milk should be immediately chilled in a refrigerator, and always if it have to travel by road or rail, for if not it soon turns, and may become very unwholesome.

Determination of Fat and other Solids in Milk

Numerous processes have been practised or proposed, but they are mostly modifications of three distinct methods. (1) The extraction of the fat by means of ether or carbonic sulphide from the dry residue, (2) from the fluid milk, the fat having been saponified by an alkali, and (3) from the fluid milk, the casein and sugar having been previously destroyed by strong hydric-chloride. In every case the total solids are determined by evaporation of a measured, or better of a weighed quantity of the milk, and for all ordinary purposes it is unnecessary to distinguish between the casein, and the sugar; the determination of (1) the total solids, (2) the fat, and (3) the solids not fat being sufficient. It is better to deal with small than with large quantities of milk, for in the prolonged exposure to heat required by the larger the residue undergoes changes. 5 ccs. or better 5 grms. are enough.

(1) Evaporate 5 grms. to dryness in a platinum basin and weigh while hot for the total solids. Evaporate a like quantity, stopping short of complete expulsion of the water. Triturate repeatedly with warm ether, using a glass rod, filtering the washings over a beaker. Then cut up the filter, steep the pieces in ether which add to that in the beaker. Evaporate the ether and

weigh; by deducting the weight of the beaker that of the fat is obtained, and this deducted from the weight of the total solids gives that of the solids not fat.

(2) The second method or Soxhlet's requires a special apparatus, and the percentage of fat may be estimated by tables from the sp. gr. of the ethereal solution.

(3) But the third, Schmid's or Gerber's process, is in every way preferable, for the extraction from the dry residue is always incomplete, and Soxhlet's method has other defects. In Schmid's process 20 ccs. of milk with 20 ccs. of strong hydrochloric acid are shaken together in a special form of tube and cautiously brought to the boiling point, when the solution acquires a deep brown colour, from the conversion of the sugar into maltose, and becomes perfectly clear, excepting a small floating coagulum of lacto-albumen or pepton, the casein having been transformed into the uncoagulable acid albumen. It is then cooled under a cold water tap, shaken up with 25 to 30 ccs. of ether, and left to stand for about fifteen minutes. A portion of the ether dissolves in the watery solution, but the whole of the fat is contained in the floating layer, the coagulated lacto-albumen resting on the plane of contact between the ether and the brown subjacent liquid. An aliquot part of the ether is then carefully removed by means of a pipette, evaporated, and weighed. If an attempt were made to decant off the whole of the etherial solution the coagulum of lacto-albumen would be disturbed.

Gerber's process is unapproached in simplicity and rapidity for the routine estimation of the fat. The apparatus are a centrifugaliser worked by hand power, butyrometers and pipettes or burettes. The reagents pure sulphuric acid S.G. 1·82, and amylic alcohol S.G. 0·815 to 0·818. Ten ccs. of the acid are measured into the butyrometer, then 1 cc. of the alcohol, and lastly 11 ccs. of the milk, each being introduced gently so as to float on the other. When the milk has dissolved the butyrometer is waved to and fro to mix the liquids thoroughly, and stood for ten minutes in water-bath at 140°—170° F. before being placed in the centrifugaliser. After three minutes rotation it is again stood in the warm water for five minutes, and the percentage of liquid fat at once read off.

All dishes, &c., whether of platinum, glass, or porcelain, should be numbered and their weights entered in a book. The weighing should be repeated about every three months, and the entries corrected, since all vessels suffer a progressive loss of weight from the action of reagents and the friction of cleaning.

So long as the "dry" methods of milk analysis were alone available for accurate determinations, a great deal of ingenuity

was devoted to attempts at discovering some less tedious process; but what was gained in rapidity was more than outweighed by the uncertainty and fallaciousness of the so-called "ready methods."

Schmid's and Gerber's processes have rendered all such expedients superfluous, being at least as rapid, while more accurate, and applicable alike to fresh and to sour curdled milk, to dry residues, and to condensed and sweetened milks.

BUTTER

The essential constituent of butter is the fat of milk which is always accompanied by serum albumen, but there is also a variable proportion of water, whether incorporated as such in the manufacture, or derived from the retained butter milk, and salt which is added in small quantities to fresh butter, and in larger when it is intended for keeping. The percentage of water varies from eight to eighteen and of salt from one to ten.

But however it may depreciate the quality of the butter, excess of water or of salt is not legally an adulteration, the only fraud recognised as such being the substitution or admixture of a refined fat known as "margarine;" and the presence or absence of "foreign fats" is determined by methods based on three characteristics of pure butter, viz., its high specific gravity, its perfect homogeneity, and the large proportion of fatty acids volatile at the temperature of boiling water.

(1) The specific gravity of genuine butter rarely falls below 910, the usual range being from 911 to 913, those of the ordinary animal fats ranging between 902·8 and 904·5.

(2) The presence or absence of foreign fats is determined by viewing a thin film of the "butter" under a low power by transmitted polarised light; when, all extraneous light having been excluded, and the polariser turned round until the field is dark, the butter, if pure, will be seen to be perfectly opaque.

If, however, any foreign fats be present, their crystalline structure reflecting the light in different directions will give a frosted or spangled appearance to the mass, and the proportion of "margarine" may be roughly estimated by the coarseness of the coruscation.

(3) The quantitative analysis consists in the determination of the volatile fatty acids, *i.e.*, of those lower terms of the series, as the butyric, which distil over at 100 C., the temperature of boiling water.

The actual percentage is then calculated by saponifying the fat with caustic soda, breaking up the soap with sulphuric acid

and distilling over a water bath. The distillate, consisting of butyric, caproic, and other more volatile acids, is titrated with decinormal solution of caustic soda. It is estimated thus:—Pure butter, 2½ grams, never contains less than the equivalent of 12 ccs. of the soda solution, and may yield enough to neutralise 18 ccs. Other fats contain so little that the difference between this and the actual yield may be taken as representing the percentage of foreign fats added. As the sample thus examined has been previously melted and filtered it is water free, and consists of fats only, the percentage of foreign fats, the presence of which is shown by the polariscope, is inferred from the titration, though, as with milk, there is always a margin in favour of the vendors.

MARGARINE

Within the last dozen years an extensive industry has grown up in the manufacture of an imitation of, or substitute for, butter from the fat of beef and mutton. It is also largely used as an addition to the skim milk cheeses, giving them a composition resembling that of those from entire milk. The article or product in question is known in the trade as oleomargarine; but since margarine as the name of the fat has been banished from chemical nomenclature, it has by an Act of 1887 been fixed on as the designation of this imitation butter.

If made from the clean fresh fat of healthy animals there can be no objection to its use. Butter may be the most easily digested of fats, but it matters little what fat is employed, provided the proper quantity is taken, and margarine may be an excellent substitute for butter, though a fraud if sold as real butter. The fat of recently slaughtered animals, freed so far as possible from connective tissue, &c., is passed through a huge mincing machine called a "hasher" into large tanks heated by water jackets, the temperature of which is never allowed to exceed 39° C. = 103° F. Here it melts to a clear yellow oil, the water and *débris* sinking to the bottom, and a thin scum of other impurities rising to the surface. This is skimmed off and the oil run into wooden cans to cool. Soon the stearin, which has the highest melting point, begins to deposit in a crystalline or granular form, and the refined fat is transferred to the pressroom, where it is kept at a temperature of 26·5° C. to 32° C. = 80° to 90° F. It is next filtered through cotton cloths, and lastly subjected to strong pressure, which separates its constituents into a soft mass called "oleomargarine," and a hard white cake of stearin which is sold to the candlemakers. The oleomargarine thus prepared is simply a

clarified fat. To convert it into margarine it is churned with milk, coloured with annatto, and rolled with ice. It is then honestly sold as such, or dishonestly as butter, or is mixed in various proportions as an adulterant of true butter.

Cheese

The different kinds of cheese vary greatly in composition, but there is only one form of adulteration either probable or even possible. We refer to the practice largely adopted in America of adding oleomargarine to cheeses made from butter milk, thus turning out an article quite equal in nutritive value to full cheese or that made from entire milk, while obtaining the milk fat in the more lucrative form of butter. If sold in its true character margarine cheese is open to no objection whatever, and indeed is more nutritious than the poorer cheeses, as the Dutch, single Glo'ster, etc. These "filled" differ from the full cheeses only in not undergoing the change known as ripening, which consists in certain decompositions or fermentations peculiar to the butter fats. Naturally all cheeses are nearly white, the conventional yellow colour of some is given by annatto, but occasionally the rind is or has been coloured with pigments of an injurious nature.

Tea

The adulterations or sophistications of tea consist in the working up of exhausted or damaged leaves to resemble fresh, the admixture of those of other trees, and the facing or colouring of both genuine and fictitious teas.

To detect the presence of foreign leaves the tea should be soaked in hot water, and the leaves carefully unrolled so as to show their form and structure. Portions of the epidermis of both surfaces should be removed by a razor, and examined under the microscope in water, glycerine, or dammar balsam. Tea leaves are very opaque, and the examination of their structure is greatly facilitated by a simple process for rendering them transparent. A portion of the leaf is enclosed between two of the thin glass covers used by microscopists, and a weight being placed on the upper glass it is heated with a strongly alkaline solution of potassic permanganate, which rapidly attacks the contents, and later the walls of the cells. When the oxidation is sufficiently advanced the specimen is treated with strong hydrochloric acid, which dissolves out the manganic oxide, leaving a beautiful

skeleton of the leaf, which in the case of the genuine tea is quite characteristic.

An ash skeleton may be prepared by placing a portion of the leaf between two such glass covers on a piece of platinum foil, weighting the upper by a silver coin, and burning it in the flame of a spirit lamp. The ash skeletons of many different leaves may by a little practice be recognised with certainty.

Exhausted leaves can be distinguished only by chemical analysis, or by the poverty of the infusion.

Ferruginous particles may be collected by a magnet and tested by hydrochloric acid and potassium ferrocyanide, which will give prussian blue, or the same test may be applied to the ash. They used to be added to exhausted leaves in order to deepen the colour of the infusion by the production of an ink with the tannin of the leaf.

A large excess of sodium chloride will probably be found in salvage teas from wrecks, or teas damaged by the entrance of salt water into the hold of the ship.

Exhausted leaves, tea dust, and dirt of all kinds are occasionally rolled up with gum and faced to imitate "gunpowder," and a fictitious article of this kind is sold under the name of "lie tea," for mixing with the stronger and coarser kinds.

Facing consists in rolling the black teas with so-called black lead, or plumbago, and the green with china clay, indigo, and turmeric; sometimes prussian blue is used instead of indigo; and it is said that chromate of lead has been substituted for turmeric. In this case the facing would be really injurious, otherwise it is not open to serious objection, pleasing the eye and not affecting the wholesomeness of the tea. Lie tea still finds its way into the market, and damaged teas are not infrequently redressed, but the vast extension of the tea culture in India, and its lower price has rendered adulteration less profitable, and consequently less practised than formerly.

Coffee

The law allows coffee to be sold mixed with chicory, provided such admixture be stated, though no limit is fixed to the proportions which the coffee and chicory may bear to one another. Again the use of fancy names, as "French coffee," is held to constitute the article a "preparation" within the meaning of the Act, and in like manner the sale of coffee mixed with ground date stones, malt, etc., is permissible, if the mixture be described as date coffee, malt coffee, and so on. "French coffee," or "coffee as in France," consists of 60 to 75 per cent. of

chicory, and is nevertheless exempt from the application of the Act, which can only be enforced when the adulterated article is sold as pure, or perhaps as coffee, without any qualifying epithet. Some tradesmen seek to protect themselves by always putting up coffee in wrappers, having the words, "This is sold as a mixture of chicory and coffee," printed on them, thus throwing on the purchaser the *onus*, in such cases a difficult one, of proving that he asked for pure coffee. If so the purchaser should refuse to take it in such papers.

It is not enough that the fact of chicory being present should be mentioned. The actual proportion of chicory and coffee should be stated thus: "Coffee 3 lbs., chicory 1 lb.," for many persons may really like a dash, say 5 per cent. of chicory, but object to, and still more object to pay for, 50 per cent. of chicory in place of coffee. It is added not so much to please the public taste as to swell the profits of the retailer.

A preliminary examination may be made by shaking up some of the mixture in cold water in a test tube, when the oily coffee will float for some time, while the chicory rapidly absorbing the water sinks, and its more soluble constituents give a deep colour to the liquid. This affords perhaps as complete a separation as is possible by any mechanical means, and is thus a quantitative as well as a qualitative test.

But the microscopical examination, for which very moderate magnifying powers suffice, is absolutely conclusive, the characteristic structures of coffee being unlike those of any adulterant, and those of chicory and roots in general equally unlike those of coffee.

The greater part of the coffee bean is composed of small angular cells, containing in the raw state oil globules along with other matters. In roasting their outlines become less clearly defined, and the oil globules broken up and diffused, while the shrivelled contents form angular dark masses at one side of each cell. Even more characteristic are the fragments of the thin membrane contained in the cleft of the bean, which show under the microscope long oblique fusiform cells lying side by side. Starch granules are absent.

In chicory there are large oval cells, not angular or polygonal, and with small groups only of granular contents; but the most characteristic structure is the lactiferous vessels, with their scalariform or ladder-like transverse markings. Carrot, mangel-wurzel, &c., are not very dissimilar, presenting the features common to most roots; while acorns, burnt corn, &c., exhibit their respective forms of starch granule. Except in the avowed form of date and malt coffees, however, chicory is the sole or

almost sole adulterant now met with, though it may be as well to mention that some time since a quantity of fictitious coffee beans was detected, admirably got up to imitate the unroasted article. They bore roasting and grinding well, but wanted the membrane in the cleft, and if steeped whole in warm water were reduced to a shapeless mass.

Cocoa

It is very difficult to legally prove or define adulteration in the case of cocoa and its preparations. Chocolate is ostensibly a mixture of cocoa, sugar, etc., and the cheaper cocoas are avowedly mixed with starch and sugar ; indeed the public prefer a cocoa which is thick and sweet. But some limit should be fixed, for to sell as cocoa, and at a price corresponding thereto, an article consisting to the extent of 80 per cent. of potato starch and brown sugar is carrying "preparation" beyond all reason, and should be brought within the application of the Act. Indeed, a few decisions have already been obtained in such cases. No cocoa should contain less than 20 per cent. of fat, however prepared or mixed.

Beer

What constitutes adulteration must be determined by the definition we frame of beer itself. Formerly it was supposed to be a fermented infusion of malt, made more or less bitter by the addition of hops. But as brewed nowadays, it must be defined to be a fermented saccharine infusion to which has been added any wholesome bitter.

Thus the malt may be in part replaced by other saccharine substances, the hops by gentian, quassia, calumba, chiretta, &c., and the desired shade of colour obtained by the addition of burnt sugar without any infringement of the law or detriment to the health of the consumer. When the hop tax was in force the substitution of gentian, quassia, calumba, &c., was a fraud on the revenue, but this is no longer the case, and there is no medical objection to their use. The colour of a beer is supposed to depend on the degree of torrefaction of the malt, but as it is impossible always to obtain the desired tint, it is, if too pale, deepened by the addition of burnt sugar. In Bavaria, however, it has been judicially ruled that the only permissible colouring agent shall be highly burnt malt, and the only bitter principle hops, while all substitutes for malt are absolutely prohibited.

In England, on the other hand, it is only unwholesome bitters, as picrotoxine, colchicine, daphnin, or picric acid that can be made the grounds of an action; while caramel, molasses, liquorice, &c., are always employed to give the creamy character, the density and black-brown colour to stout and porter, complex decoctions unknown in Germany.

Cocculus indicus berries (of which the active principle is picrotoxine) and absinthe (*Artemisia absinthium*) are occasionally used as bitters and to render the beer more intoxicating, but such a practice cannot be too strongly condemned. Capsicum, grains of paradise, juniper berries, &c., serve to tickle the palate in various ways, and alum and sulphuric acid to give a fictitious "hardness" suggestive of age.

Salt may be present to the extent of 10 or 12 grains per gallon from the water and as much more from the materials, but anything over this has certainly been added, probably with a view to excite thirst. A common practice among unscrupulous publicans is to dilute the beer in the cask with water, and to put in a quantity of raw sugar to restore the density and give a "head." Such beer soon undergoes irregular alcoholic and acetous fermentation, becoming heady, sour, and unwholesome. Salicylic acid is sometimes added for the purpose of checking these fermentive processes, and must be considered a further adulteration.

For the chemical examination of beer and the recognition of the several adulterations we must refer the student to special works on the subject of food analysis.

WINES

There is not much adulteration beyond fortifying and colouring of wines bought at a fair price of respectable wine merchants, but those sold at public houses, racecourses, &c., and furnished by tender to workhouses, are often grossly adulterated, if not wholly fictitious.

Ports, sherries, and champagne are always fortified with brandy, ports coloured with elder or phytolacca berries, champagne sweetened with sugar, and sherries "plastered." Cream of tartar and œnanthic ether are often added to port to simulate age, or it is made up with inferior wines, and alum added, to heighten the colour. In other cases Brazilwood, logwood, or even the aniline colours, as fuchsin, are used, and since these are generally prepared with, and mostly contain, arsenic, their use is highly dangerous. Lead is sometimes found

in wine, whether introduced by accident or intentionally for clearing it.

Ports and sherries are largely manufactured at Hamburg from potato spirit, cider, &c., with various colouring matters, and so are champagnes, both here and on the Continent, from rhubarb, apples, &c.

In Germany, sound, light, still wines are sometimes aërated directly, as in the manufacture of aërated waters. It is much to be regretted that the exigencies of the excise in this country should preclude the production of a sparkling wine more pleasant and far more wholesome than even the best champagne.

The complete examination of wines demands considerable manipulative skill, and the reader is referred to larger and special works. We may, however, remark, that fuchsin easily separates, dyeing a skein of silk soaked in the wine of a rose colour, passing into yellow on treatment with hydrochloric acid, whereas in a pure wine the silk becomes a bright red. Fuchsin should always be looked for in red wines, otherwise adulterated, and if found, the wine should be examined for arsenic.

Spirits

"Fusel oil," *i.e.*, other alcohols and bye products of distillation, is present as an impurity, rather than an adulteration, in spirits distilled from raw starch, *i.e*, corn and potatoes more than when malt alone is used. If found in rum, or what purports to be wine brandy, called cognac, these have been mixed with common spirits. It is also fraudulently added to gin in the "blending" to give pungency to the taste. The adulteration most frequently made the subject of prosecutions is mere dilution with water, which in the interests of temperance and health, it is to be wished were even more general.

Vinegar

is frequently adulterated with sulphuric acid, or more rarely with hydrochloric or nitric acid. One part in a thousand of sulphuric acid is allowed by law, but some cheap vinegars consist of little more than dilute sulphuric acid coloured with burnt sugar. Less than 3 per cent. of acetic acid indicates dilution with water. In examining for sulphuric acid, it must be remembered that natural vinegar contains sulphates as well as tartrates of the alkalies.

Mustard

The mustard seed containing no starch, its presence is evidence of the admixture of wheat or other flour. Legally it is an adulteration, and convictions have been obtained, but this is to be regretted, since pure mustard would be liked by few. If, however, the quantity of flour added be excessive, requiring turmeric and cayenne to restore the colour and pungency, it may fairly be deemed an adulteration.

Pickles, &c.

Pickles, and tinned foods of all kinds, are apt to contain copper and lead derived from the vessels in which they have been boiled, or the soldering of the cans. It would be much better that all acid and oily foods should be put up in bottles or jars. The lead may however be derived from the so-called "tinning" of iron cauldrons, &c., which often contains so much as to differ little from solder. The whole question of copper poisoning from food is involved in doubt and obscurity at present. Copper is still very generally added to pickles to restore the green colour lost in boiling, but of late a solution of chlorophyll derived from grass or other leaves has been used for the same purpose.

Anchovy paste is reddened by bole armeniac, a ferruginous earth, or formerly, and perhaps occasionally now, by red lead. The same is true of cayenne pepper.

Annatto is subject to much adulteration ; and lime juice, like vinegar, may be little else than mineral acid and sugar.

Jams

Plum, "household," and other cheap jams are largely composed of a pulp made from refuse apples, vegetable marrows, &c. In the case of raspberry jam this dilution is concealed by the addition of the seeds, skins, &c., left behind in the manufacture of raspberry syrup or vinegar. A little practice will enable a fair microscopist to recognise these fraudulent admixtures by their structure.

Honey

Much of the honey now imported from America is adulterated with, or even consists entirely of a syrup made by the action of oxalic acid on a glucose prepared from the starch of maize.

Summary of Chapter IV.

The flesh of animals that have died or been killed when suffering from disease can be recognised by an expert, as can the earliest stages of putrefaction. Such meat is always more or less unwholesome. But under certain ill understood conditions, meat originally sound develops, through the action of bacteria, **toxic substances, ptomaines or alkaloids** of almost inconceivable virulence ; and a poison is easily formed in milk if certain precautions are neglected. The flesh of animals suffering from specific infectious and septic diseases should always be condemned, though in the case of tuberculosis still local and incipient, and of such parasites as flukes and tapeworms, the affected organs only need be so ; but the entire carcases of cattle with advanced and general tuberculosis, and of swine with trichinæ or cysticerci (measly pork, as it is called), should always be destroyed. Tuberculosis and foot-and-mouth disease (epizootic eczema) are directly communicated by means of milk.

Moulds render flour unwholesome, but ergot is the most poisonous, and pellagra is ascribed to *inter alia* the use of damaged maize.

Adulteration of food consists in the addition of anything, whether in itself injurious to health or not, to fraudulently increase its bulk or weight, to conceal its inferior quality, or in any way cause it to be of a different nature or quality from that which was asked for or expected. Thus the addition of water to **milk**, or starch and sugar to **cocoa**, or margarine to **butter**, or the substitution of rice or potato starch for **arrowroot** is equally a fraud with the addition of copper to **pickles**, fuchsine to **red wines**, &c. Abstraction of cream (fat) from milk is a fraud, but the removal of some of the fat from cocoa, and the addition of some flour to mustard cannot be fairly held as such. Unfortunately the saving clause exempting articles described as "mixed" or "prepared," or as "French" coffee and the like, opens a door to extensive evasion of the law. The addition of alum to damp and damaged **flour**, enabling the baker to produce a bread of good appearance, is recognised as a fraud, but that of rice to **wheat flour**, rendering the bread capable of retaining an additional six to 10 per cent. of water, and reducing to that extent the nutritive value of a given weight, is not one in the sight of the law.

"Filled" **cheeses,** *i.e.*, cheese from skim milk, from which the butter fat has been removed, and margarine, a prepared beef or mutton fat, added in substitution, are equally nutritious with genuine "full" cheese, and may be sold if their nature be indi-

cated, but their sale as ordinary cheese is a fraud, and the same rule applies to margarine and butter which must not be mixed, though margarine may be sold under its true name. "Arrowroot" has not been legally defined, but the substitution or addition of other starches to that of the maranta may be recognized by the microscope.

Milk. The SG about 1035 is the resultant of those of the nearly constant casein and sugar, which are heavier than water, and of the inconstant fat which tends to lower it, the milks richest in cream being the lightest. Watering milk lowers the S.G. as skimming raises it, the utter uselessness of the "lactometer" as a test of quality is thus evident. These are the only frauds ordinarily practised, though retail dealers often add as preservatives boric acid or formic aldehyd to carry over surplus milk from day to day.

"**Milk analysis**" is practically limited to estimation of fat, and if that be deficient, of the solids not fat also, or S.N.F., as they are collectively called. A rapid approximation to the proportion of fat may be made by *Gerber's* centrifugalisation of a small quantity of milk with amylic alcohol and H^2SO^4, in which it dissolves and separates. If apparently deficient an exacter estimation may be made by *Schmid's* method, in which the casein having been rendered incoagulable by boiling with HCl, the fat is separated by ether, evaporated and weighed, and the S.N.F. estimated by deducting this weight from that of the total solids after evaporation.

For cases in which extreme precision is wanted, *Soxhlet's* process must be followed.

The usual standard is water 87·5 per cent., total solids 12·5 per cent. = fat, 3 2 per cent., and S.N.F., 9·3 per cent., but this is too low, inviting fraudulent treatment of a milk with fat 4 per cent., and S.N.F., 10 per cent. **Condensed milks** are evaporated in so-called "vacuum pans," to one-fourth of their bulk, with, or, but rarely, without the addition of 20 to 30 per cent. of cane sugar. **Butter** consists of 80 to 90 per cent. fat, albumen 1 to 2 per cent. The water varies in fresh butter from 7·5 to 14 per cent., but is always high in sa't butter, in which 15 to 16 per cent. of salt and of water may reduce the fat to less than 70 per cent. But though the retention of the butter milk deteriorates a butter, the only legal adulteration is the admixture of margarine, *i.e.*, butcher's fat carefully prepared with the removal of so much of the stearin as to leave it of the consistence of butter. Its sale as such is legal, but no admixture of butter and margarine is permitted. The presence of "foreign" fats in butter is shown by the appearance of their crystals under the polariser, and proved by the proportion of non-volatile to volatile

fatty acids after saponification. There is little adulteration of **tea** since its price has fallen, but spoilt teas may be re-dried and "faced" with colour; the black being plumbago, the green indigo and turmeric, though dangerous mineral pigments have been used.

Coffee is largely adulterated with chicory, unless pure coffee be demanded. The detection of chicory and of other roasted roots and seeds is easy under the microscope.

Cocoa is still more constantly "prepared" or adulterated by the addition of cheap starch and brown sugar, and the abstraction of more than is necessary or excusable of the fat. Detection is, however, easy.

Beers are largely made with "substitutes" for malt and for hops, and are treated with sugar, alum, &c., to give body, "head," and clearness. Wines are often made up from inferior kinds, and are sometimes wholly fictitious.

Spirits. The only adulteration commonly met with is dilution, but "fusel oil" is sometimes added in so-called blending, and turpentine added to common spirit to simulate gin.

QUESTIONS ON CHAPTER IV.

1. What are the principal adulterations of milk, coffee, cocoa, mustard and beer, and what is the importance of each? 1887,E.

2. What are the most frequent adulterations of bread, and how are they detected? What is the importance of each? 1888,A.

3. What diseases of cattle render their flesh unfit for the use of man? State what you know about the effects produced by the consumption of tainted or putrefying meat, and by what substances they are caused. 1891,H.

4. Describe the process of breadmaking and explain the changes which take place in the flour. Upon what data would you give an opinion of a sample of flour submitted to you? Explain briefly any analytical process you would adopt in order to arrive at an opinion. 1896,H.

5. How would you recognise diseased and wholesome butcher's meat? What diseases may be produced in man by the consumption of the flesh of diseased animals? 1897,A.

6. What diseases of the cow may be communicated to man, unchanged or changed in their characters by the use of the milk of animals suffering therefrom? How may such results be prevented?

7. Of what diseases proper to man may cows' milk be a vehicle?

Of which is the cow herself believed to be susceptible, and which are conveyed by infection of milk after it has been drawn?

8. What is the composition of butter? Describe a good method of determining the amount of volatile fatty acids present in a sample. How does the determination assist in deciding the question of adulteration? 1900, H.I.

9. Describe Wanklyn's method of milk analysis, and the newer processes of Schmid and Gerber. What are the advantages presented by these apart from the question of time?

10. What is the "standard" composition of milk accepted by analysts as regards fat and solids not fat? To what extent does it permit of adulteration or impoverishment with impunity?

11. How can dilution of milk with water be distinguished from addition of "separated" milk by their respective influence on the several constituents?

12. What changes in character and in wholesomeness may milk undergo by agitation during transit in warm weather, and how may they be prevented?

13. What is the usual adulteration of butter? Give a ready method of detecting it qualitatively.

14. What are the usual adulterations of wines? What the limits of alcoholicity in a natural wine? What is "plastering," and what deleterious changes does it produce?

15. What is meant by "malt substitutes" and "hops substitutes" in brewing? What is the effect of the former on the beer? and to what special dangers are they open? Is there any serious objection to the several substituted bitters?

16. What addition is made to the malt in the production of the cheaper whiskies, and to what ill effects does it give rise?

17. What is the usual adulteration of vinegar, and is there any excuse for the addition?

18. What are the most frequent adulterations of mustard and arrowroot? How may they be detected, and how do they affect the value of the products?

19. What substances are used in the adulteration of coffee? How would you detect the presence of (1) chicory and (2) ground beans?

20. How are cheap cocoas prepared? What are chocolate, flaked cocoa, and "*soluble* cocoa"?

21. State the legal definition of adulteration and criticise the "saving clauses." Of what amendments are they capable in the interests of the consumer?

22. What is measly pork, and what condition does it give rise in man? What is trichinosis? How may the two diseases be recognised in pork?

23. What internal, not intestinal, worms enter the body from water in tropical countries?

24. What form of tuberculosis is propagated by milk, and what precautions should be observed to prevent it?

CHAPTER V

Clothing

Besides serving for decency and adornment, and guarding certain parts of the body from mechanical injuries, the use of clothing is to assist in the maintenance of the animal heat under external changes.

The normal temperature of the body—98° to 99° F.—is constant, for with the air, as it generally is, at a lower temperature, the heat lost by radiation is kept up by the oxidation processes within the organism, which are, when necessary, economised by the withdrawal of blood from the superficies of the body, so as to minimise the loss by radiation; and, on the other hand, when the external temperature approaches or exceeds that of the body so that the production of heat would tend to exceed the loss, it is compensated for by increased cutaneous circulation and consequent radiation, and by rapid evaporation (perspiration), the cooling effects of which are well known.

The habits of some races, as those of tropical Africa, and the experience of the Turkish bath, show that the human body possesses an extraordinary resistance to external heat, but its power of resisting cold is far less, even among the rudest of savage tribes. Clothing serves to lessen the strain placed on the organism under either circumstances, diminishing the loss of heat from the body in the one case, and protecting it from the effects of external heat, and especially from the direct rays of the sun, in the other.

To do this, the materials used should, as a rule, be bad conductors of heat either way, for though the people of

India, at least the middle classes (the poor using no more than is necessary for the protection of the head and for decency), set the example of wearing cotton, which is a good conductor, the practice is one of very doubtful expediency. Cotton and linen keep off the direct rays of the sun, and favour the loss of heat from the body, but being bad absorbers of moisture they are apt, when the temperature falls, or the production of animal heat is lessened through fatigue or otherwise, to interfere with evaporation from the skin and cause dangerous chills. Loose white flannel, as worn by Europeans in India, and by boating men and cricketers everywhere is far better under such circumstances.

The materials employed in clothing are:

1. Vegetable fibres, as cotton and linen.

2. Animal fibres, as wool and silk, and the hairs of other animals woven into fabrics.

3. Mixtures of the two classes.

4 Skins, tanned or untanned, and with or without the hair.

5. Fabrics rendered air and water proof by coating with indiarubber.

Linen and cotton are good conductors of heat, especially the former, and very non-absorbent of moisture, whether into the substance of the fibres or into their interstices. Silk and wool are bad conductors; silk for equal thicknesses being the more so, but its price precludes its general use except for external adornment, though thin silk vests are very agreeable for wearing next the body. Wool has also a remarkable power of so completely absorbing moisture that it feels dry when cotton or linen would be wet and cold. Its value as a non-conductor retaining internal and excluding external heat is well shown by its use in "cosies" for teapots on the one hand, and for packing ice on the other.

"Flannelette," much used of late for underclothing and night-wear, consists of cotton, but resembles flannel in its

texture, and from the amount of air contained in its interstices, is little inferior as a non-conductor and absorbent.

The young and the old, the rhemuatic, all persons liable to colds or weak in the lungs, or who have suffered from kidney diseases, those who are exposed to great heat or cold, or are engaged in laborious exercise, ought to wear flannel next the skin, and indeed every one would be the better for doing so. If it be found too irritating for delicate skins, at any rate in summer, merino, a mixture of fine wool and cotton or silk, or flannelette, may be substituted, and the "cellular" clothing is admirable.

Rheumatic subjects and persons liable to cold feet will find it a great luxury to sleep in blankets in winter, and young children who are apt to get uncovered at night should wear flannel nightgowns next the skin in winter, and over cotton ones in summer. In washing, woollen articles should never be boiled, wrung, or rubbed hard.

Leather affords an excellent protection against cold, and is quite impervious to wind. The neat kid jackets lined with wool and worn under their coats by Danish farmers deserve to be adopted more generally.

Furs have the additional recommendation of handsome appearance, though to get the full value out of them they should be worn, as in Eastern Europe and Central Asia, with the fur inside. Trimmings of fur are more ornamental than useful.

Waterproof clothing, *i.e.*, indiarubber, is absolutely impenetrable by wind or rain, and under many circumstances is indispensable. It is often urged against its use that it retains and condenses the perspiration, but if not worn constantly, if it be loose and thrown open when it is not raining, and above all, if a sufficiency of woollen clothing be worn beneath, these objections have no weight compared with the enormous advantages it presents.

The colour of clothing is a matter of little importance

in the shade, but in the sun the best reflectors are coolest, such as white and light greys, while blue and black are the worst as absorbing the most heat.

Dark colours also absorb odours, &c., more than light ones, and the black woollen dresses worn by hospital sisters are most improper. Indeed, for everyday use light coloured garments, of whatever material, provided it can be washed, are to be recommended, though dark colours are preferred, because they do not *show* the dirt! What woman would like to wear a cotton print or muslin six months without washing, yet it would not be half so dirty as the more absorbent dark woollen dress that she would wear as long without a scruple.

Bedding and Bedclothes

Soft, and especially feather, beds are weakening. The harder a bed, consistently with comfort, the better. Good hair mattresses are the most wholesome; but flock, if clean, are unobjectionable. The leaves of the sea wrack, *Zostera marina* (or, as it is erroneously called, Alva), make a clean, light and cheap stuffing.

The sanitary or Liverpool mattresses of wire twisted on a wooden frame are a great improvement, even on the spring mattress, which is very apt to get out of order.

Coverings should be light, pervious to the evaporation from the body, and yet bad conductors of heat. The down bedcover and cushion used in Germany with a sheet make an ideal bed. Our blankets are too heavy, and thick cotton counterpanes are heavy without being warm. Flannel or flannelette night-dresses are much to be preferred to cotton at all times both for comfort and for health. Warmer in winter, they obviate the chill of the cold sheets, while in summer they prevent the more dangerous chill when in the early morning hours the

external temperature falls, when the production of internal heat in the body is at its lowest ebb, and the skin perhaps bathed in perspiration, a chill which otherwise can be avoided only by an unnecessary amount of bed clothes.

There are few persons who do not know more or less of the discomforts of cold feet at night, at any rate after the first hour or two after getting into bed, and some cannot sleep restfully without a footwarmer. I would advise all such to try the plan of introducing between the sheets a blanket folded lengthwise across the lower half of the bed, and firmly tucked in on either side. It will then reach to the waist of the sleeper, the non-conducting wool retaining the natural warmth of the body, instead of abstracting it as the cotton or linen does, and obviate the necessity for an oppressive weight of bedclothes.

At the risk of being deemed a faddist I must express my opinion that our whole system of bedding and night-clothing needs reform, and any one who has tried the experiment of sleeping in flannel nightdress and warm dressing-gown with the legs in a blanket sac, and in cold weather a rug spread loosely over all, will agree with me as to the luxury of warmth without weight, and "ventilation" without cold. Such is the principle of the Indian "sleeping costume" of flannel shirt and "pyjamas" and of that of the sensible if eccentric Dr. Jäger, adapted in details to the different climates.

Errors and Follies in Dress

Whatever objections may be urged against closely-buttoned black cloth coats, and the uncomfortable and hideous chimney-pot hat, it cannot be denied that in this age male attire, if not artistic, is, at any rate, not injurious to health, and that whenever the usages of society permit men most sensibly prefer the easy jacket, knickerbockers, felt hat, and shooting boot, or canvas shoe. On the matter of boots we shall have something to say, but even here they are not so bad as the other sex.

But in women's dress there is scarcely an article from head to foot to which grave exceptions cannot be taken, and though physicians and satirists have condemned or ridiculed the fashions of each succeeding age, there seems little hope at present of any real reform. Extravagances may have been abated, but the more serious errors are still persisted in.

Passing by the palpable inconsistencies of evening dress, in

which the upper part of the trunk containing the lungs is uncovered and exposed successively to the heated atmosphere of ball-rooms and to the chill night air, when the power of resistance is lowered by fatigue, as being confined to certain classes and particular occasions, we shall limit our criticisms to the everyday dress of women of all ranks alike. We shall say nothing of headgear, in which custom allows the utmost latitude of choice, and which, except in exposure to extremes of heat or cold to which women are seldom subjected, is a matter of indifference. We may observe that the distribution of female clothing is irrational. The high dress is often the only covering of the upper part of the chest, which is scarcely better protected than when the dress is low. The middle of the trunk is tightly encased in stays and clothing, and the hips are encumbered by a weight of skirts out of all proportion to the warmth they afford to the lower limbs, which, in fact, are only thinly covered with loose cotton, but which make walking always fatiguing, and in windy weather well-nigh impossible. Coming to details, we first encounter the stays, though the task of denouncing tight-lacing is like slaying the slain, and as regards its probable results is no better than cutting off the hydra's heads. In women, indeed, so large a part of the respiratory movements is performed by the upper ribs that it does not interfere so greatly with that function as it would if practised by men, but the compression of the lower ribs affects most injuriously the no less important organs of the heart, stomach, liver, &c. The heart's action is impeded to such an extent that any additional unfavourable condition is followed by fainting, and this derangement is increased when from any cause the stomach is distended with air. The change of position and movements of this organ during meals and digestion are likewise interfered with, leading to various forms of dyspepsia, which give so much employment to the doctor. The liver is squeezed and forced downwards below the lowest ribs; its functions as well as those of the intestines suffer; and, lastly, the muscles of the back become wasted and powerless.

Neither on physiological nor on æsthetic grounds can a word be said in favour of tight-lacing or of wearing stays at all. It seems to be a vulgar notion that without them women would have no figures, *i.e.*, no waists whatever, and that their sides would describe an ugly straight line from armpit to hip, but that this is an utter delusion an inspection of any of the much-admired statues of Venus is enough to show. Real living Greek women were models, and they certainly did not wear stays.

In the infant, as the old Italian painters well knew, the waist is

the widest part of the trunk, and in the young girl there is no waist to speak of, but with the development of bust and hips at puberty the woman acquires a waist, the curves of which are drawn on the lines of perfect beauty, as unlike those of the *modiste's* dummy or its living copy as those of a racehorse are to the wooden "gee gee" of the nursery. The waist of the normal woman is wider than it is deep, while the waist of the fashionable woman is as round as that of a Dutch doll.

A tendency to stooping, round shoulders, or curvature of the spine, is a sign of weakness of those muscles whose duty it is to maintain the erect posture, and should be met by games and suitable gymnastic exercises calculated to strengthen these muscles, not by putting the back into splints and thus depriving them of what strength and tone they have left.

If girls were allowed to indulge as their brothers do in the natural play of their muscles, they would grow up as erect and lissom as they, and would enjoy a health and graceful bearing more often seen among savage than civilised races.

Of course, if women, as age advances, show a tendency to corpulence and flaccidity of muscle, there is no objection to their wearing an easy-fitting corset of stout jean without bones, but if their muscles had been allowed to develop freely this would rarely be necessary.

Boots, as worn now, are as faulty in principle as stays. The aim of the shoemaker seems to be to make the longitudinal axis of the foot a straight line and each foot bilaterally symmetrical. With the hand, indeed, this is the case. The middle finger is the longest, and those on each side of it nearly correspond ; but we are not like monkeys, quadrumanous. The great or inmost toe is the longest and in a line with the side of the foot, while the others are successively shorter. The long axis, too, of the foot describes a curve, of which the concavity is inwards, and the right and left feet are exactly the converse of one another. The absurdity of pointed toes and still worse of reversible shoes is manifest enough, and the consequences are bunions or inflammation of the joint of the great toe, from its being forcibly turned towards the middle line, overlapping the others, so-called "ingrowing" toe nails, and corns.

Again, the natural sole is not flat, but forms an arch of wonderful mechanism, the function of which is interfered with by high heels as worn by both sexes ; but when, as in women's boots of late years, the heel is also tapered to a point and slanted forwards, the whole machinery of walking is thrown out of gear. The weight of the body then rests on the roots of the toes ; the ankle joint is kept in its weakest position with the

astragalus half out from the socket, and liable to twist; while a painful strain is thrown on the muscles of the calf, the hams, and even the back, so much so in some cases, more than one of which have come under the author's notice, as to simulate disease of the spine, though cured by a week's rest and slippers.

Even when the boots are made to measure, the case is little better; the shape of the sole is not taken, and the foot being measured when raised from the ground, no allowance is made for the natural expansion in walking. Every time the one foot is raised, the other which bears the weight of the body, expands one-twelfth of its length and about an eighth of its breadth at the base of the toes. In measuring, the foot should be firmly planted on a sheet of paper, and the outline of the sole described with a pencil. The German army boot is the best in Europe, and some of the most successful strategetic movements in the war of 1870 would have been impossible but for the extraordinary marching powers of the troops.

Instead of the multitudinous bands and tapes constricting the abdominal organs at the waist, the skirts which need not be so heavy if woollen nether garments were worn, might be suspended by buttons to an easy-fitting and boneless substitute for the rigid corset, or by a broad band above the crest of the hips; braces or shoulder straps, being open to objection.

Garters, again, are a fertile cause of varicose veins, which are far more frequently met with among women than men.

The cause of female dress reform has suffered much from injudicious advocates. That so long as the lower limbs and pelvis are scantily covered and exposed to cold air, heavy petticoats afford the minimum of warmth with the maximum of inconvenience in walking is self-evident, and that adequate protection from cold is to be obtained only by some nearer approach to the male attire is equally clear, but it is idle to imagine that women will ever adopt the "Bloomer" costume, even in the modified form suggested by Lady Harberton.

But it is quite possible to attain the same end without the least appearance of unfeminine apparel. Combinations of natural wool and knickerbockers of serge, tweed, silk or flannelette, according to the season, fitting close at the knee, and affording attachment for the stockings, dispensing alike with garters and the less objectionable but unsatisfactory "suspenders," with boneless stays, would alone, or with the addition of a vest and of a single extra skirt under the dress, afford ample protection against cold, without being too heavy in summer, and allow a freedom of movement and a relief from fatigue in walking to which women are at present strangers.

But, while these changes can be effected without being seen, there is one even more to be desired on hygienic grounds, though we fear that science and common sense will declaim in vain. A woman walking in a dirty street or country road, her wet skirts flapping at her heels, and, as well as her stockings, bespattered with mud, is a sight at once pitiable and contemptible. Should she escape the misery of wet and dirt by carrying her dress on her arm she only exchanges it for fatigue and inconvenience, rendering really healthy exercise impossible. How much illness, to say nothing of discomfort, would be prevented, and under certain circumstances even accidents averted, by the general adoption of short dresses, short enough to be well clear of the heels and always dry and clean, leaving the arms as free as those of men? That short skirts necessitate good boots or shoes is in itself no small advantage. Whatever may be said in favour of the æsthetic effect of a train in the drawing-room or ball-room, women themselves, perhaps unconsciously, admit the advantages of the short skirt in the dresses they adopt for shooting, fishing, and mountaineering, and its picturesque appearance in the preference they show for the pretty costumes of the Highland or Continental peasantry at fancy balls.

Whatever the materials they should be pervious to air, as tested by the ease with which one can breathe through them; and whatever form the dress may take it should be loose enough to admit of the free access of air, and if possible at times of light, to every part of the surface; as the costumes of ancient Greece and Rome did perfectly, rendering the body far less sensitive to changes of temperature than when it is encased in close fitting garments. In infancy and in old age warmer clothing is of course required.

The growing practice of "weighting" textile fabrics is a fraud, injurious alike to the tissue, the health of the wearer and the true interests of commerce. Unlike the mixing of cotton with wool, or of jute with silk, it is wholly inexcusable. Muslins are stiffened with gum, cotton and linen goods laden with starch and earthy matters, black silk may consist in great part of "dye" and dirt and even cloth and serges are treated with zinc chloride, a caustic salt which by absorbing moisture adds to the weight.

The dyes, too, are not always harmless. As with wall papers, so with wearing fabrics, arsenical pigments are occasionally used. Some green tartans have been found to be heavily laden with arsenite of copper, easily detached, and symptoms of poisoning have followed the use of sage green and other woollen materials. The bright anilin colours, fuschin, &c., often, indeed generally, retain some of the arsenic used in their manufacture,

and stockings and gloves of these hues frequently give rise to painful inflammation and eruptions of the skin. Arsenic, too, in forms easily detached, is also largely, we might say universally, used in the colouring of artificial flowers, to the serious injury of the work people and occasionally of the wearers.

Clothing may be rendered incombustible by being steeped in a solution of tungstate of soda, 1 lb. to 2 gallons of water, or if starched, by adding one part to every three of starch.

Dust and Dirt

Dust of some kind is everywhere present, even in the higher regions of the atmosphere, though varying widely in quantity and composition. It consists of minute fragments and particles, inorganic and organic, dead and living. Among these there may be easily recognised by the microscope fine particles of sand raised by the wind, the wear and tear of roads and vehicles, dried horse dung, pollen grains, and the spores and cells of algæ, fungi, and bacteria, these organisms, with spores of all kinds, being found even at great altitudes. Indoors, and around our houses, we have in addition soot, the *débris* of animal and vegetable structures and fabrics of every description, scales of insects, and epithelium from the skin and lungs, with often, could we distinguish them, the germs of infectious diseases.

These being the constituents of dust, the importance of avoiding everything which may afford a lodgment for it is obvious. Such are elaborate cornices, flock papers, immovable furniture, dark corners, ill-fitting floor boards, and fixed carpets reaching to the walls. If the floors can be plugged, stained, and waxed or varnished throughout, and the carpets beaten out of doors instead of being swept in the room, so much the better, but at any rate a wide margin of such prepared flooring greatly facilitates the removal of the dust. Dust should, indeed can, be removed from floors, ledges, &c., only by a damp cloth; in "dusting" as commonly performed it is simply driven from its resting places to settle down again so soon as

the air is still ; and the mechanical sweepers are much better than brooms, which wear away the carpets, creating more dust.

Baths and Bathing.—The dirt of the skin, and of underclothing, consists of the sweat and greasy matters exuded from the pores, together with the cast-off epithelium. The importance of frequent, if not daily ablutions, will be better appreciated when we consider what are the functions of the skin, and the amount of solid and fluid matters excreted thereby. The quantity varies enormously according to the temperature and humidity of the air, the work done, and the fluids drunk, but is probably never less than five pounds, or half a gallon daily, and with hard labour in a high temperature this amount may be lost in an hour. From 1 to 2 per cent. of this consists of fatty solids, without taking into account the cast-off epithelium. Profuse perspiration tends to dislodge the crust of grease and scales which adheres to the skin so long as the perspiration is insensible, though it may impart an unpleasant odour to the clothes by which it is absorbed, and the gentleman of sedentary habits may stand in greater need of the bath than the gas stoker, though he may be less offensive to his neighbours. Of this he may easily satisfy himself by observing the result of shampooing after a Turkish bath.

For purposes of cleanliness a bath without soap and friction is perfectly useless, and warm water is more effectual than cold. The shock of a cold plunge or sponge bath has a powerfully invigorating influence on the nervous system, and arms against the risks of catching cold, but the ends of health and cleanliness alike will be best attained by the daily use of soap with cold water, and once a week with warm.

Speaking of cold baths, we may notice a popular error as to what constitutes such. The temperature of the body is always a little under 100° F. If then in summer a bath at 60° F. or 40° under that of the body is con-

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sidered cold, and gives the desired amount of shock, it will do the same in winter, and to insist on plunging into water at 40° F., *i.e.*, 60° below that of the body, is, to say the least, unreasonable. A cold bath then is one at 40° or 45° below the temperature of the blood, and is the same in January as in July. To break the ice, as some do, is prompted by misapprehension or bravado, and may be followed by dangerous consequences.

Water is a better conductor than air, and abstracts heat rapidly from the body if much below the temperature of the latter. At the same time it contracts the vessels of the skin, and drives the blood to the internal organs, engorging those of the lungs and taking away the breath. A vigorous heart soon overcomes the impediment to the circulation by increased action, and consequent production of heat. But there is a limit to this effort, and when it is reached, the depressing influence of cold on the ganglionic nervous centres becomes evident, and failure of the heart or syncope follows. In this, and not in cramp, as is commonly supposed, lies the danger of open air bathing. A good swimmer, if seized with cramp, will be still able to float, but if he faints he sinks helplessly in a moment. It is dangerous to bathe after a full meal, but not less so when fasting, and nearly all cases of drowning will be found to have been of persons bathing before breakfast. An hour or two after breakfast is a good time, but if one wish to bathe earlier, a light repast, as an egg and a cup of coffee, should be taken previously. Again, it is dangerous to bathe when exhausted by fatigue, but the glow of moderate exercise is a decided advantage. A light refreshment and a short run or brisk walk are the best preparation for a swim, which should not be prolonged until fatigue or chill is felt, and should be followed by a rub down, speedy dressing, and a quick walk home.

When the resisting and rallying power, and the circulation generally are weak, as shown by shivering, coldness

of the extremities, and sense of exhaustion, sea and outdoor bathing should be given up. So, too, persons whose lungs and hearts are weak, and above all, those who have any actual disease of those organs, or have ever spat blood, should not attempt it.

The Turkish or Roman bath has of late been deservedly gaining in popular favour. It is based on the power which the human body enjoys of resisting external heat by increased cutaneous evaporation for which the air must be dry. A longer or shorter time is passed in rooms at temperatures rising successively from 80° or 100° F. to 160° or 180°, and if the bather can bear it, to 220° or above that of boiling water. To resist baking, the cutaneous perspiration flows fast, and should be aided by free potations of water, to maintain the tension of the blood vessels, and allow the excess of fluid to pass off from the skin, which acts vigorously. The surface of the body is next cleansed by soap and friction, gradually cooled by a spray passing from hot to cold, braced by a cold plunge, and hardened off by rest in a cool apartment.

All derive pleasure and benefit from the Turkish bath, except persons whose hearts are weak, but it is especially valuable to those whose skins do not naturally act well, or who suffer more or less from defective elimination, the dyspeptic, rheumatic, and gouty, and persons of sedentary habits and good living.

The ancient Romans combined the bath and gymnasium, an example deserving of imitation. Such a Roman bath has been, so far as we know, established at Glasgow only.

The vapour bath, the temperature of which cannot, for obvious reasons, be carried to anything like the same height, differs little in its action from the warm bath; and is in Russia alternated with the cold plunge.

The really hot bath, as hot as can be borne without pain, is not depressing as is the warm one, but a power-

ful stimulant to the skin and circulation, and in cold weather the glow it imparts persists for hours. The Japanese who are, from the richest to the poorest, the greatest bathers in the world, revel in temperatures of 110°—115° F., intolerable by a European unless he have educated himself up to that degree, but the very best effects are obtained by the alternate use of the cold and hot bath in close succession.

Soaps are chemical combinations of the fatty acids with alkalies, which decompose the crude fat, liberating glycerine. Soda is used if a hard soap is desired, and potash if a soft one. Castile soap is made with olive oil, for others beef or mutton fat and palm oil are employed. Yellow soap contains rosin, and some others petroleum in small quantities. In most there is a slight excess of alkali, but though this enhances the detergent or cleansing power of the soap, the amount of free alkali present in some which are most useful for laundry and household purposes is such as to unfit them for the toilet. For delicate skins the pure neutral curd soaps would be the best, but unless specially prepared, they are inconveniently hard and insoluble. Recently, superfatted soaps have been produced, containing much lanolin, the fat obtained from wool, and, unlike all others, miscible with water. Fancy and medicated soaps are of various degrees of merit, and the colouring not always innocuous : the transparent kinds are made from ordinary yellow soap by dissolving it in alcohol, but for "old brown Windsor" the dirtiest residues of the vats and scrapings of the floors are available, and the perfume of bitter almonds is simulated by nitrobenzol.

There is an adulteration very generally practised in soap-making which does not come within the operation of the adulteration Acts, these being limited to foods and drugs. It is called in the trade "liquoring," and consists in the addition of 5 to 25 per cent. of soluble silicates, which enable the soap to hold a large amount of water,

to prevent the escape of which the bars are exposed to the heat of an oven until a horny crust is formed on the surface. Liquored soaps are not injurious but wasteful, dissolving rapidly in water if used when fresh and moist, or shrinking and losing weight if cut up and left to dry. Liquored soaps on section have a homogeneous tallowy white appearance, without the wavy look due to the crystallisation of the fatty acids exhibited by pure soap. Sugar, too, is largely used as an adulterant in the manufacture of transparent soaps.

Parasites

The human body is liable, both without and within, to the attacks of various organisms, animal and vegetable. In the light of modern pathology all infectious and infective diseases are of this nature, but we shall here limit the expression to its ordinary acceptation.

A number of skin diseases more or less contagious are due to, or rather consist in, the growth of minute fungi or moulds. Such are the various kinds of ringworm, chloasma, and favus. Of these, the last, now rare in this country, causes such irritation as to lead to the exudation of a gummy or albuminous fluid, which hardens into a scab, and so disfigures the child that medical advice is sure to be sought.

Chloasma is marked by patches of greenish purplish hue on the body. It is met with only in dirty persons, because mere soap and water suffices for its removal.

Ringworm, on the other hand, attacks the clean and healthy, no less than the uncleanly and weakly, among rich and poor. It is easily transplanted by mere contact or exchange of hats and caps. At first so trifling as almost to escape notice, it may become so inveterate as to baffle treatment for a long time. It attacks the hairs of the scalp or the finer hairs of the body, penetrating their substance, and causing them to split and break off, leaving on the head spaces at first stubbly and ultimately

bald. On the surface of the body it presents a ring of a reddish colour where it is advancing around a whitish scaly central area. Later on it penetrates the roots and follicles of the hair, and is then as hard as it was at first easy to cure. If, on its first recognition, the patch is well painted with tincture of iodine, or solution of corrosive sublimate (1 per 500), or moistened and touched with a stick of caustic, it will be at once destroyed. Should this prove ineffectual, medical advice should be called in. The infected headgear should be destroyed. The popular remedy, ink, is useless, and involves a waste of precious time.

Thrush is a species of mould, *Oidium albicans*, which attacks the unhealthy, and mostly ulcerated mucous membrane of the mouth in young and feeble children, especially those artificially or improperly fed, though it may occur in infants at the breast if their digestions are disordered. It is important to bear in mind that it is only an indication of gastric and intestinal disturbance, of which it is but an accidental, howbeit a pretty constant accompaniment, and that, however expedient or necessary it may be to remove or destroy the parasitic growth, attention should be mainly directed to the prevention and treatment of the primary and essential disease.

It was regarded by Hallier as identical with the *Oidium lactis*, and it is certain that milk in the least degree soured, or a dirty bottle or tube will almost inevitably induce it. Medical advice should immediately be sought as to the feeding and medical treatment of the particular case, the most scrupulous care being observed as to the freshness of the milk or food, and the cleanliness of bottles, &c. Every speck of the oidium should be wiped off with a camel's hair brush or the finger and corner of a handkerchief. The infant should never be allowed to sleep with the bottle, and if it be feeble it is a very good plan to rinse out its mouth with a teaspoonful or two of water after feeding, that no stale milk be left behind.

Various parasiticides may be used locally, as glycerine and borax, or solutions of sulphite of soda, chlorate of potash, &c.

The popular remedy, honey and borax, is worthless, the honey favouring its growth and detracting from the efficacy of the borax. My own practice is to destroy the oidium, if abundant, by a single application of a pretty strong solution of nitrate of silver with a camel's hair brush, to direct almost exclusive attention to the dietetic and medical treatment of the cause, and restrict the local treatment by the mother or nurse to frequent wiping and washing of the mouth with plain water.

The vulgar notion about the thrush "passing through" the infant is an utter mistake; the inflammation and eruptions that appear simultaneously on the buttocks and legs are not thrush in any sense of the word, but are due to the irritation caused by unhealthy urine and fæces, and, as may easily be observed, are almost confined to the parts in contact with the napkins. These should be changed as often as damped or soiled, if not dispensed with altogether for the time, while the lower parts of the infant's body should be sponged, not merely wiped, after each act of micturition or defecation, and then anointed with lanoline, not powdered. Vaseline often irritates the skin.

Animal parasites attacking the surface of the body are itch and the several species of louse, for fleas and bugs, though feeding on the blood, do not take up their habitation in the skin or hair. The female itch insect it is that causes the characteristic symptoms and annoyance, for, burrowing beneath the cuticle, she lays her eggs at the end of her run, and the young, when they hatch, set off in various directions, following the example of their mother. The *acarus* may be dug out by a needle if carefully sought. The irritation they produce is intense, and leads to eruptions of all kinds, scaly, pimply, blisters and mattery heads. Sulphur ointment is the usual remedy; others are more effective in medical hands; but sulphur is the safest for domestic use. At the same time the skin should be scrubbed with soft soap and hot water, and fresh ointment applied daily. This scrubbing removes the loose scurf scales and exposes the insect to the action of the ointment.

Lice are quickly killed by saturating the hair with an ointment of white precipitate or oleate or nitrate of mercury to which a little carbolic acid may be added with

advantage. The eggs or nits, however, are not destroyed, and continue to hatch for some time. Methylated or other spirit dissolves the resinous matter by which they adhere to the hairs, they may then be removed by a fine comb.

Internal parasites are of many kinds, but we need not describe those peculiar to tropical countries. Excluding these, as guinea worms, &c., we have two species of threadworm which it is not necessary to distinguish, roundworms, trichinæ, and tapeworms. There are others, as flukes, but these are sufficient for our present purpose.

Threadworms are minute white worms inhabiting the lowest part of the bowel, rarely extending beyond the last 6 to 10 inches. They breed in the human body, but whence derived and what their habits elsewhere, is not clearly known. They cause great annoyance and vague and varied symptoms by the irritation they create. "Worm powders," mostly sharp purgatives, should be avoided, since they generally do more harm to the child than to the worms, which may soon be exterminated by the daily use of an injection of a quarter to half a pint of water, with or even without a teaspoonful of common salt to the pint. The injection is most effectual if used after the bowels have been opened, as the worms are then uncovered. It should be retained for some minutes, especially if it be used without the salt.

The **Roundworm**, or *Ascaris lumbricoides*, is so called from the general resemblance it bears to the common earthworm, with which it is often popularly supposed to be identical, though of a somewhat different shape and more transparent. Its natural habitat is the water of rivers and ponds, with which it enters the human body, where it is mostly found in the small intestine, though occasionally travelling up or down to either extremity of the alimentary canal. It is rare that more than one or two are present, though they have been found in great numbers, and the symptoms they cause, if any, are as a

rule so trifling that their presence is not suspected until they are passed with the stools or in rare instances vomited. If there be any reason to suppose that they are there, a powder of santonin, followed by an aperient, will decide the question. The worms entering the digestive canal when young, attain a considerable size, and lay their eggs, which may be detected under the microscope by thousands in the stools, but cannot hatch and be developed within the body. For this purpose the eggs must find their way again to the water. The human body is a temporary and not a necessary lodging for the young adult.

Trichinæ are microscopic worms which pass their entire existence within the bodies of animals more or less carnivorous in their habits. Their lives are divisible into an active and reproductive period passed in the intestine and a quiescent stage in the muscles. Man usually receives them from the pig, as being the only carnivorous animal used for food. The gastric juice dissolves the capsules in which the dormant worms were enclosed in the muscle substance. They escape and breed in the bowel in enormous numbers, causing severe disturbance and diarrhœa. The young worms soon pierce the walls of the blood vessels, and are carried by the circulation until arrested in the capillaries, when they make their way into the fasciculi of the muscles, become encysted or coiled up in egg-shaped capsules, and undergo no further change. The symptoms now are fever, emaciation and soreness or severe pain in every limb and muscle, which may cause death from exhaustion, or the patient may survive and the worms as well as their capsules undergo degeneration. If the host be a pig it is usually killed and eaten before the worms have lost their vitality, and the terrible disease of trichinosis results. But this is absolutely confined to those countries where people are in the habit of eating pork, bacon, or ham raw or merely smoked. Curing generally kills them, and

thorough cooking never fails to do so. A few cases have occurred, from time to time, in America, mostly among Germans, but not one in England, France, or Germany, has been traced to the use of American pork, in which the worms when present are always dead or nearly so. Every German, Russian, and Swedish epidemic has been caused by eating home-fed pork half raw.

If diarrhœa, &c., can be traced with any reasonable probability to the ingestion of ill-cooked pork, ham, &c., brisk purgatives should be given, and the evacuations examined microscopically. The more thoroughly the bowel can be cleared of the trichinæ the fewer will be left to penetrate the tissues; when they have done so nothing remains but to support the patient's strength until the worms have become quiescent and cease to cause any irritation.

Tapeworms belong to an entirely different class. All the preceding were bisexual, and possessed of digestive apparatus, &c. The tapeworm is a compound animal with scarcely any organs except those of reproduction. It consists of a so-called head, or it might more properly be called root, the size of a very small pin's head, from which extends a neck or stem marked by transverse rings, and gradually becoming flatter and wider until it appears as a long chain of joints or links of an oblong shape, about an inch long by half or a third of an inch wide, the entire chain extending to a length of some yards, and occupying the whole course of the intestine below the spot where the head is attached to its wall. Each joint is hermaphrodite, and when the contained ova are matured the joints break off singly or in sets and are evacuated. The joint decays, and the eggs set free are eaten by some animal, usually the pig. They hatch in the stomach, and the embryo, called a scolex, which resembles the head of the mature worm, bores its way into the blood vessels, and lodging in the muscle or liver, develops around it a bladder or capsule, where it remains in a quiescent state until the

flesh is eaten by man or some other animal. The scolex now liberated attaches itself to the wall of the intestine, and begins to develop the chain of segments which constitute the tapeworm or tænia. Two distinct hosts are thus needed for its cycle of existence—in the muscles of one of which it lives as a scolex, and in the bowel of the other as a tænia. The scolex of the mouse is the tænia of the cat, and other species are in like manner shared between the fox and the rabbit, and so on. The tapeworms of man are of three species, one of which is the scolex of the pig and another that of the ox. Occasionally man becomes the host of the larval or scolex stages, which are then called echinococci or hydatids. The scolices retain their vitality for years, and the tænia head for an indefinite time. The presence of scolices in the flesh of the pig constitutes the so-called "measly pork." The heads of both species of tapeworm are provided with suckers, and that of the *Tænia solium* from the pig has a circle of hooklets which are wanting in the tapeworms of the ox or *T. mediocanellata*. In Eastern Europe mankind is subject to another tapeworm, *Bothriocephalus latus*, of a very different appearance, which has been quite recently proved to pass its scolex stage in the body of the pike and other fresh water fish.

"Measly pork" should always be avoided, though thorough cooking can scarcely fail to kill the parasite ; but tapeworms are generally expelled without difficulty by a dose of extract of male fern taken after the bowel has been thoroughly cleared by fasting and aperients. The worm should be then burned *pro bono publico*, and not allowed to enter the sewers to continue its species.

Summary of Chapter V.

Ideal clothing should permit of free movement of all the muscles, of the limbs, body, and internal organs, protect from external heat and cold by being a bad conductor of heat in

virtue of its material or its texture, be a good absorbent of moisture, and admit of the access of air, and, so far as possible, of light to the skin ; loose soft textures fulfilling these requirements best, and cotton or wool, flannelette being nearly as good as wool, are better than linen or silk. Yet under special conditions impervious clothing, waterproofs, or preferably leather or furry skins, fur inside, may be preferable for temporary wear. White and light colours absorb less heat and are cleaner.

Bedding and bed clothes should be chosen on like principles. Beds should be as hard as can be borne, never of feathers, the covering warm in cold weather but not heavy, permitting of ventilation and evaporation. Blankets not exceeding two, down quilts preferable. Pyjamas are rational, especially in summer. In winter feet kept warm as by blankets, better than by footwarmers. **Women's dress** errs in many respects ; stays should not be used for supporting the back, while causing the muscles to waste ; knickerbockers should take the place of cotton drawers and heavy skirts, of which one should be enough, and the shorter the better ; to need holding up is absurd. **Boots and shoes** should fit the natural foot expanded by pressure on the ground, the inner side being straight, the toes broad, and heel low. The **danger of dyes** containing arsenic, and not fast, is real. Silk hats are abominations ; the Norfolk jacket or reefer, gaiters and felt or straw hats, make the best dress for men.

Frequent bathing with soap is necessary for perfect health, and cold baths for all who can bear them, but the cold bath must rarely be under 60°, and should never be as low as 40°. So-called "Turkish," properly "Roman" baths are very healthful, especially for the sedentary and rheumatic, and all whose excretion is not active. Soaps should not be strongly alkaline.

Ringworm is a mould that penetrates the root cavities of hairs, both those of the head and the downy hairs of the neck, &c. **Thrush**, another mould that attacks the mucous membrane of the mouth, especially in feeble infants, or those whose digestion is impaired.

Itch is a true parasite, the female burrowing and laying her eggs under the skin. Other vermin are external. **Threadworms** live and breed in the rectum, **Ascarides** live in the bowel but leave it to lay their eggs in water. **Tape worms** pass their "larval" stage in the flesh of another animal, as the pig, and their sexual in the bowel of man ; but man may be the host of the larvæ if he swallow the eggs. **Trichinæ** live in the bodies of carnivorous animals, dormant and encysted in the muscles of

one, but free, active and prolific in the stomach of another that devours the former, and into whose muscles they soon penetrate, as when a man eats imperfectly cooked pork or ham. There are many other parasites in tropical climates, as guinea worms, Bilharzia in the kidneys, &c. **Flukes** occasionally invade the human body in one or other of their developmental phases.

QUESTIONS ON CHAPTERS V. AND VI.

1. What is the importance of cleansing the skin? What are the results of want of cleanliness? 1884, E.

2. At what periods of life is warm clothing most necessary, and why? 1887, E.

3. Describe the appearances (under the microscope) of silk, wool, and cotton fibres, and state the advantages of each as a material for clothing. 1888, E.

4. What are the best materials for clothing in hot climates, and why? 1891, E.

5. What animal parasites may be found on the surface of the body, and how may they be got rid of? 1891, E.

6. Name the parasites infesting man derived from his food and drink, and describe the life history of any three of them? 1894, H.

7. What is soap, and why is it essential for washing? 1895, E.

8. Distinguish hard and soft soap. What are the adulterations practised on the former?

9. Discuss woollen, cotton, and linen clothing in respect of their conductivity to heat, and hygroscopic characters. Also leather and rubber clothing. Why should clothing be permeable to air?

10. Why do damp sheets cause chills, which blankets under like conditions do not?

11. What are the ill effects of tight lacing, garters, and narrow and high heeled boots?

12. Why are down quilts better than blankets, and these than heavy cotton quilts? hair than feather beds? and why should rheumatic persons and those with feeble circulations sleep in blankets rather than in sheets?

13. Why is "flannelette" warmer than calico, though like it made of cotton?

14. What is the effect of exercise on the heart and general nutrition? What evils result from the abuse of running and cycling? Discuss the comparative merits of gymnastics and outdoor exercises.

15. What are the effects and advantages of hot and cold baths? What is the Turkish or Roman bath, and its effects on the system? and contrast it with the Russian or vapour bath. What constitutes a cold bath?

16. Discuss the special advantages of swimming as an exercise, and the muscles strengthened by rowing.

17. What exercises conduce most to the expansion of the chest and increase of capacity of the lungs? Do singing and the use of wind instruments tend to strengthen the lungs in health, and under what conditions should the latter be deprecated?

18. What are the effects of mountaineering on the heart and lungs, and of the respiration of rarefied air? To what ill results may they give rise?

19. To what injuries may diving and the respiration of compressed air conduce?

20. What are the essential principles of "training," and its influence on the muscles when conducted with prudence and when pushed to an extreme?

21. What diseases and constitutions are more or less certainly hereditary? In what does heredity consist? Can heredity be correctly predicated of tubercular consumption, and, if not, in what does the observed tendency thereto in certain families really consist?

22. What injuries to health are known to be caused by arsenical pigments in wall papers and fabrics? Are any colours more frequently arsenical than others? What means would you employ to detect the presence of arsenic? Is the popular application of strong ammonia solution to the paper a trustworthy test, and if not, why?

23. Why do symptoms identical with those caused by arsenic sometimes follow the wearing of socks or other articles of clothing dyed with aniline colours, as fuchsine? Under what conditions may arsenical pigments be used without danger?

CHAPTER VI

HABITS, EXERCISE, REST, ETC.

WELL-BUILT and properly arranged houses, pure air and water, good food and sufficient clothing and cleanliness of the person, are all of them more or less essential to

the enjoyment of a normal and healthy existence. But not less so are a judicious amount and alternation of exercise and rest, without which the most perfect surroundings may be rendered unavailing, and which, on the other hand, tend to confer on the organism a marvellous power of resisting conditions in themselves unfavourable to health, and are withal perhaps more under the control of the individual than are any of the foregoing.

Exercise

Regular and not excessive exercise of a muscle, alternated with duly proportioned periods of rest, tends to increase its bulk, hardness, and contractile power, while disuse causes it to become flabby and to waste. This is true of the muscular system as a whole and of single muscles or groups of muscles, with this difference that when the development is general the nutrition of other organs, and consequently the performance of their functions, shares in the beneficial effects. Carried to excess and without the due alternation of periods of rest, exercise may lead to exhaustion of nutrition and to wasting or degeneration, though it is seldom that the motive to exertion is strong enough to induce a voluntary agent to carry it to this pitch. Yet it has been observed in the University boat race that when a crew has been "overtrained," and two or three of their number have, after the usual loss of fat and water and gain of muscle, again lost weight in the last week or fortnight preceding the race, they have, however good their form, been invariably beaten.

Training is the art of bringing men of average strength and ordinary habits in a short time to a state of muscular development equal to the performance of extraordinary feats of exertion or of endurance, and is apt to be followed by a reaction. Regular and systematic exercise is more conducive to health and to the permanence of the desired

condition of nutrition and strength ; and the amount of work done by the labourers in some foundries, by Indian coolies and others, is such as no one could achieve by any short course of training. In either case, if the work be suddenly and completely broken off, the consequences are a rapid deterioration of health and strength, though, on the other hand, the results of judicious exercise in early life remain in vigour of body and mind prolonged to advanced age.

The consequences of neglect of exercise are seen in the extreme case of a limb confined for many weeks in a splint, which wastes until it becomes for a time almost powerless. In lesser degrees neglect of exercise is followed by a feeble muscular development, which may exist along with fair health, intellectual activity, and long life, as in the case of many men of studious and abstemious habits, but they have, as a rule, little power of resisting external unfavourable conditions, and are often wanting in strength of character and courage. When sedentary habits are associated with high living, obesity, fatty degeneration, accumulation of waste matters in the blood, dyspepsia, gout, gravel, and premature decay sooner or later follow, though not always together, for impaired digestion may induce emaciation, or one form of degeneration may follow on another.

The first effect of a course of systematic exercise or training is a loss of weight due to the removal of fat and water, most marked in those who are inclined to be stout or flabby ; this is followed by a real gain in weight, in girth of chest and limbs and in lung capacity. The muscles become hard, the blood richer, and the general nutrition and repair more active. The rapidity with which pugilists in training recover from contusions and injuries is well known.

Effects of Exercise—On the Lungs.—The amount of air inspired and of CO_2 expired is remarkably increased. Dr. Ed. Smith found that if the air inspired in the re-

cumbent posture were taken as 1, that in standing was 1·33, in walking one mile per hour 1·9, two miles 2·76, three miles 3·23, four miles 5, six miles 7, and so on.

Pettenkofer and Voit's observations on a man who passed certain days in complete rest, and on others was for several hours engaged in moderate labour, with an enormous increase in the absorption of oxygen and the elimination of carbonic acid and water (given on p. 14), show the importance of avoiding anything in dress or posture that may interfere with the free action of the lungs during labour, and the necessity for the amplest supply of fresh air in workshops and gymnasia.

On the Heart.—The force and frequency of the heart are increased, but remain regular so long as the exertion is not excessive or too prolonged. After the effort is over it falls below the normal, and, if the labour have been exhausting, may become rapid, feeble, and irregular.

Excessive exertion in persons not previously accustomed to it may lead to hypertrophy and dilatation of the heart, and when the vessels of the lungs are weak to their rupture and spitting of blood.

This is especially the case with running, and the embarrassment of the heart consequent on the obstacle presented by the engorged state of the lungs is painfully familiar to most men. The art of escaping this, and if it come on, of getting one's "second breath" consists in avoiding undue acceleration of the heart, and in practising steady, deep and full respiration while running, which is more difficult the greater the pace. "Sprinting" and long distance running involve very different conditions, and the former should not be attempted by men over thirty unless in the best condition and training. Cross-country running, in which endurance counts for far more than speed, is a grand and healthful exercise, but even it should not be carried to a point when it becomes painful. Thus many young men engaged all the week in sedentary occupations have produced valvular disease of the heart by weekly runs with "harriers," without adequate and judiciously graduated training in the intervals. This is especially the case in cycling, in which the movement becomes

automatic and fatigue is not felt. Judgment and discretion should be exercised in riding ascents, but scorching and record-breaking are contemptible.

Walking is free from any such dangers, but to be of service must be really hard walking and not strolling or promenading.

Perspiration is enormously increased and calls for the imbibition of water, which should be taken frequently, though in moderate quantities each time, so long as the loss by the skin and lungs goes on.

Digestion is improved, as is the nutrition and vigour of the organism generally. The highest mental and intellectual energy is compatible with great physical development, unless the cultivation of the former be, as is too often the case, neglected in the exclusive attention to the latter. Many of our most successful university men and most eminent lawyers, bishops, and statesmen have been in their early life foremost in every kind of athletic exercise.

All exercise to be beneficial should call into play the muscles of every part of the body, a rule too often forgotten by empirical gymnasts. In this, as well as in the open air, and the mental exhilaration, consists the superiority of field sports and outdoor games over many artificial systems of gymnastics, though gymnastics conducted on truly scientific principles are of the greatest value, especially when the freer exercises cannot be enjoyed, as is the case with the hardworked denizens of towns ; and even without any apparatus it is not difficult to arrange exercises that shall develop every group of muscles including those of the abdomen and flanks commonly little used.

In early youth it is better to encourage and give free scope to the natural instincts to frolic and play, at any rate no apparatus should be used, and this rule should be observed to a later period in the case of girls. The notion that it is unladylike for girls to run and romp is one that cannot be too severely condemned. They are to be the mothers of our men as well as of our women, and

advantage should be taken of everything calculated to give them the highest physical development and energy attainable by their sex. Most of the ailments of women which form the largest part of the doctor's work would be prevented if girls were encouraged to strengthen their muscles, lungs, hearts, and digestions just as their brothers do, not excepting cricket. When the muscles have acquired greater firmness, and the ossification of the bones is approaching completeness, more severe exercise is permissible and desirable, and the time has arrived for systematic gymnastics. These should be adapted to the differences of sex and to the strength of individuals. Into the details of this subject our space forbids us to enter, but we may notice a few points of special importance.

In the use of apparatus the weight and strain should be gradually and carefully suited to the strength. Much harm is done by premature or suddenly increased efforts, especially under the influence of emulation. Girls should avoid such exercises as are attended by the risk of displacing certain internal organs. The system of exercise to music, though imparting wondrous grace and harmony of movement, is apt to become wearisome, and should at any rate be varied by the emulation and freedom of the German system. Dumb bells, clubs, bar-bells, &c., should not exceed 2, 3, or 4 lbs. for girls, 4 or 6 lbs for boys, and should only gradually be increased to 8, 10, or 12 lbs. for men.[1]

When circumstances permit a man to enjoy walking, riding, rowing, football, cricket, or field sports he scarcely

[1] *Effects of Gymnastics.*—Dr. Burcq states that experiments conducted during six months at the Ecole Normale de Gymnastique Militaire furnished the following results;—1. Increase of the muscular force by 23 or even 38 per cent., and, as a mean, by from 15 to 17 per cent., the two sides of the body being at the same time brought into equilibrium. 2. Increase of the pulmonary capacity by at least one-sixth, as a mean. 3. Increase of weight by from 7 to 15 per cent., giving a mean of 10 per cent., and that with a decrease of bulk, the whole gain being muscular, as attested by the dynamometer.

needs any more, but for the townsman, an hour or two twice a week at a well-conducted gymnasium will often, as Sandow has proved in his own person, transform the weakly youth into a robust and powerful man. Cycling, too, not only calls into play the muscles of the arms, legs, and back, but enables the rider to enjoy the pure air of the country, when he would otherwise be tempted to seek amusement in the billiard room, the music hall, or worse.

This however does not apply to the attitude assumed by the "record breaker" and the "scorcher" on the road, whose existence is the bane of cycling, with head bent forward, back and shoulders rounded and elbows raised, though excusable in the exigencies of the racing path. The cyclist who seeks health and recreation should maintain an erect posture and postpone all considerations of speed to style and exercise, making his ride a source of pleasure and of health.

Rowing or sculling should be practised in the same spirit, when it is a valuable form of exercise, but only when associated with others. It is a general but erroneous belief that rowing develops the chest; as a matter of fact it does the very reverse; the muscles called into action being those of the forearm and legs, and in heavier boats of the upper arm and back. In no part of the stroke is the chest expanded, and many noted oarsmen are remarkable for the narrowness and defective development of the muscles of their chest. In swimming and the use of dumb-bells, &c., the rowing man would find at once a corrective and an aid.

For women and elderly men incapable of violent exertion, golf and lawn tennis are good, and dumb bells supplemented by walking will suffice for many who could not otherwise enjoy any muscular exercise. The advantages of swimming are obvious, but one is, that it calls into play muscles which no other exercise does, *viz.*, those of the posterior and scapular regions. This it is that makes it so fatiguing to those unaccustomed to it. Men engaged daily in laborious employments stand in little need of gymnastic or athletic exercises which are more useful to those whose work is mental and sedent-

ary; but these not unfrequently fall into the error of ignoring the necessity for some degree of training or preparation before undertaking unaccustomed exertion. It is not without danger, and certainly it is with no beneficial results that a man in middle life rushes from the counting house or study to the Alps, though one who even in London is in the habit of walking, say five miles daily, or of taking equivalent exercise, may, if spare and muscular and sound in lung and heart, take his holiday on foot and do his twenty miles a day; yet even he would not be the worse for a fortnight's preparation before a holiday on the mountain or the moor.

Sunstroke and **Heat Apoplexy**.—It had long been a matter of common observation that symptoms not unlike those of apoplexy, *i.e.*, loss of consciousness, sometimes sudden, at others preceded by a feverish sensation, prostration, vertigo, nausea, pains in the head, &c., and occasionally attended by temporary delirium, mania, or convulsions, followed exposure to the direct rays of the sun; hence the term sunstroke; but it has been found, especially in the experience of our Indian army, that the same effects may be produced, even at night, by confinement in ill-ventilated and over-crowded chambers under a high temperature, which had led to the substitution of the less convenient but more correct expression, heat apoplexy. Why should it not be called simply "heat stroke"? The immediate cause in all cases appears to be the failure of the organism to resist the tendency of exposure to external heat to raise the internal temperature of the body.

So long as evaporation from the body is active, the highest temperatures can be borne with impunity, but any conditions tending to impede it favour the production of heat stroke. Such are a humid atmosphere, a clouded sky, close rooms, tight clothing, alcoholic excess, and fatigue. Thus, while our soldiers in India frequently suffer in barrack, and on full dress parades, or when marching in close order, it is unknown in Turkish

baths, and extremely rare in the rainless regions of Colorado, &c.

In all cases there is an actual elevation of the body temperature, congestion of the vessels of the brain, depression of the functions of the pneumogastric nerve with engorgement of the lungs and heart. Nearly 40 per cent. of well marked cases are fatal.

Water must be taken from time to time to supply the loss by evaporation, and the "restraining of the thirst" urged for the avoidance of drinking polluted waters is itself a dangerous practice.

The treatment is first to *pour cold water on the head*, then remove the patient to a cool airy place, take off all heavy clothing, sponge the body with cold water, and give ammonia and ether, and light nourishment. Bleeding is useless. Ice to the head is the best remedy.

Sleep

No general rule can be laid down as to the number of hours which should be passed in sleep, since the need of sleep varies with age, sex, temperament, and the way in which the waking hours have been employed.

The infant slumbers away the greater part of its time. Young children should sleep from six or seven o'clock in the evening till morning, and until three or four years of age rest in the middle of the day. Up to puberty the hour of retiring should not be later than eight or nine, while adults require seven to nine hours, say from eleven at night to six, seven, or eight in the morning. Some can do with six, and a few with five hours, but this is mostly the result of an acquired habit, which cannot be persevered in for many years with impunity. Persons who are not engaged in any severe work, whether bodily or mental, require comparatively little sleep, as the hard working student or professional man finds when he indulges in a holiday; muscular fatigue of itself tends to

induce sleep,—"the sleep of the labouring man is sweet," —and he awakes refreshed. But brain work too often causes wakefulness, although sleep is even more necessary for the repair of brain than of muscular tissue. In such cases the attention should be forcibly withdrawn from study for some time before retiring to rest, and turned to some light reading, song, music, or conversation, or if possible, absolutely suspended. A short brisk walk, a pipe, or a weak glass of spirits may aid in inducing sleep. Drugs should be avoided, but ten to twenty grains of bromide of potassium, or in extreme cases a dose of five or ten (not more) grains of chloral taken with the consent of a medical man who has suggested every other resource, is better than a restless night to be followed by a day of hard intellectual work. But this should only be resorted to as a temporary expedient, for an entire change of scene and abandonment of work for a time, is the true remedy. After a heavy supper either sleep or digestion must suffer, but hunger is incompatible with sound and refreshing sleep; those who dine late do not need a supper if they retire before eleven or twelve, otherwise a light repast may be taken with advantage an hour or two before bed time. Brain workers and city men do best to take a light lunch, and a dinner after the day's work is over; but literary men who write late do well to rest for a time, after the evening dinner, and again before lying down. To such the pipe and light reading or music are specially valuable in diverting the train of thought.

Ordinary persons do best to retire at ten or eleven, and the habits of society which compel indulgence in later hours are much to be regretted, but no great harm can, as a rule, result from staying up to eleven or half-past. Brain work after midnight, however, is most exhausting, and though perhaps brilliant, is too often hasty and ill considered. Whatever be the explanation, it is an indisputable fact that day and night cannot be exchanged.

About one or two A.M. the heart's action sinks, and nature points to the necessity of rest. Sleep in the day time does not compensate for the loss of that at the proper time, and slumbers prolonged to a late hour do not refresh the mind or body as does sleep between the hours of eleven and six or seven, the normal period for rest.

Old persons require, as a rule, less sleep than those of middle age, just as they require less food, because their nutritive processes are less active than when they were younger, and perhaps, because their mental efforts also, are less forced and attended by less exertion and more deliberation.

Women, generally speaking, require more sleep than men, at least under like circumstances, obviously because in their case the same efforts induce greater fatigue.

Habit

This is not the place to discuss the moral and social advantages of regularity and punctuality in every circumstance of daily life, but its importance from a physiological point of view is not sufficiently realised. The more often and regularly any act is performed the more automatic it tends to become, and the less effort, whether mental or physical, attends its performance. This is a matter of daily experience and observation, and is true, not only of mental work and manual or mechanical exercises, but of the organic functions of the body. Quite apart from the harm done by too frequent eating or too prolonged deprivation of food or want of rest, the brain finds itself ready for sleep, the stomach for digestion, and the bowels for action, at the same hour every day when these acts are solicited and performed with unbroken punctuality, and the friction, so to speak, of the organism is reduced to a minimum.

Idiosyncrasies

By these are meant certain peculiarities in the constitution of individuals, manifested by their behaviour under certain conditions, or the action of particular agents on them in a manner different from that in which the same agents act on others, and which, though clearly the effects of these conditions or agents, are not easily explained. They are best seen in the effects of certain articles of food or drugs on the stomach and directly or indirectly on the nervous system, and of certain odours on the nasal and bronchial mucous membranes. Among foods which, though taken with impunity by most persons, produce severe gastric disturbance and eruptions, as nettlerash and erythema, in others, the chief are pork, crustaceans and shell fish, eggs, onions, &c. Among drugs, opium and morphia cause wakefulness in some, and are taken by a few without any effects whatever. The scents of certain flowers, which to other persons are most agreeable, produce in a few severe catarrh, and the contemplation of the waves from *terra firma* will cause sea-sickness in some, while no amount of pitching and rolling disturbs the gastric equanimity of others.

As with drugs so with the poisons of certain diseases, some individuals appear to enjoy complete insusceptibility. The subject is an interesting one, but little if anything is really known about it. Moreover, this insusceptibility or susceptibility is not always possessed by the same persons at all times; and lastly idiosyncrasies are often hereditary.

Heredity

That physical, mental, and moral characteristics are inherited by children from their parents or remote ancestors is a fact too well known to need more than a mere mention. The children of a thief or a drunkard will, unless subjected to strict discipline, become thieves and drunkards even though early removed from the influence of example, just as they may inherit the family features. Those of the miser will be misers or run into the opposite extreme of reckless extravagance. Sometimes the features and character are formed by a combination of those of both parents, or the bodily peculiarities of one are joined to the mental characteristics of the other; or the child exhibits a reversion to and reproduction of those of a more distant ancestor or

relative. This is sometimes distinguished as atavism. Acquired habits and aptitudes are in like manner capable of becoming hereditary, a fact familiar in the case of sporting dogs.

Hereditary Disease.—This is a matter of the highest interest in preventive medicine. One disease only, syphilis, is immediately transmitted by the parent to the progeny. In all others it is not, strictly speaking, the disease but the predisposing causes of the disease that are inherited, and the consequences may be averted by avoidance of the exciting causes. Thus gout is the visible outcome of a certain imperfection in the functions of assimilation. This imperfection is inherited, but the actual manifestation of gout may be prevented by careful avoidance of everything calculated to overtax the digestive and assimilative functions. The same remarks apply to diabetes and to rheumatism, but the association of rheumatism, chorea (St. Vitus's dance), and heart disease other than the immediate consequence of rheumatic fever, and the occurrence of one or the other in different members of a family, are very curious. Again, insanity is not directly transmitted, for no one ever saw a mad baby ; but a peculiar irritability, that is susceptibility of the cerebral centres to slight stimuli, a want of co-ordination and of inhibition, makes the child of insane parents an easy victim to the same malady. A proneness of the cells to take on peculiar forms of abnormal growth, as cancer, is inherited, though the immediate cause may be a parasite, and some families show a susceptibility to scarlatina in its most malignant type, while in others it is of the mildest.

But the disease in which the factor of heredity seems to play the most important part is undoubtedly *tubercular* phthisis. Every form of tuberculosis and so-called scrofula being, like all other infectious diseases, due, as recent research and experiment have placed beyond all doubt, to the entrance into the body of a specific bacillus, it is impossible to conceive of their being any more hereditary than those diseases are. To this statement we must make one qualification. Several cases have been collected of late years in which the fœtal calf and in a few the human infant have been found at or before birth to be the subjects of tuberculosis directly transmitted from the female parent. Observation and experiment on animals have also shown that the milk of a tuberculous female may contain numbers of the bacilli in question, and that the disease is thus directly transmitted, making its appearance most often in the glands of the mesentery, by which it would naturally be arrested ; while pulmonary tubercle is of most frequent occurrence in later years in the children of tuberculous parents. The true explanation is

doubtless that such children inherit a feeble power of resisting the bacillus, which finds in them a suitable soil, this susceptibility to tuberculosis under unfavourable surroundings being shared by the children of parents not actually tuberculous, but whose constitutions have been broken by dissipation or exhausting disease.

Closely connected with the question of heredity, is that of marriages into families having some hereditary taint, and of intermarriages among the members of such families, or indeed of the same family under any circumstances. A certain school of sociologists argue that if the same care that has been given to the breeding of horses were everywhere observed in the marriage contract the race might be improved to an extent that we can hardly imagine. So it might be in one sense, but man is not merely an animal; and it is certain that had such restrictions been always enforced, many of the best and greatest men —men who have left their mark for good on the world—would never have been born; while it is not improbable that the general result might have been a reign of brute force and lawless violence, a race of "mighty" men like the giants of fable or of antediluvian tradition. Yet rational man should exercise a certain amount of prudence. Persons actually suffering from disease or deformity, or in whose families these are so strongly pronounced that reappearance in their offspring is inevitable, are not justified in marrying; and unions between two families tainted in like or in different manners, and those between members of the same family under such conditions, cannot be too strongly deprecated.

> "Ætas parentum, pejor avis, tulit
> [Hos] nequiores, mox daturos
> Progeniem vitiosiorem."

But those with members of healthy families serve to weaken, and ultimately to obliterate, such tendencies, and if the physically inferior be mentally or morally superior, the results may be highly satisfactory. Intermarriage *per se*, "in and in breeding" may be undesirable, but the melancholy consequences often seen are probably due rather to the inevitable intensification of every family defect, for where, as in many isolated, especially insular, communities, as yet uncorrupted, all are equally and perfectly healthy, no such deterioration is observed, and it would seem that they could gain little, if anything, and might lose, by the introduction of new blood. Such are the Faroe islanders, with the lowest known child-mortality, and more deaths in the eighth decade than in any other!

Summary of Chapter VI.

Active muscular exercise, even brisk walking, increases the amount of oxygen inspired and absorbed, and of CO_2 and water vapour given off, quickening and strengthening the heart's action and the general nutrition of the body, the muscles actually engaged increasing in bulk, while fat and water are withdrawn from the tissues. If carried on in excess of the power of repair, or on insufficient diet, wasting ensues. In the muscles of the heart there is a limit to increase, after which the cavities dilate under the pressure caused by the resistance presented by the lungs to the passage of the blood, and the valves become incompetent. This result follows continued acceleration of the heart's action from whatever cause, as running, especially when not in training. **Professional cyclists** and those who aim at speed and distance are especially prone to suffer. **Sunstroke** follows direct exposure of the head to the sun's rays, but heat stroke may occur indoors and at night if evaporation be checked; soldiers on the march should maintain the mass of fluid in the circulation by drinking small quantities of water to compensate loss by evaporation. **Sleep** is very much a matter of habit, but whether six, eight, or nine hours be required it is better to retire and to rise early, and to cultivate the habit of avoiding causes of wakefulness, and drugs alike.

Heredity.—Gout, rheumatism,and other defects of nutrition and metabolism, heart disease, insanity, and instability of the nerve centres, and perhaps cancer, are inherited, though the tendency thereto and to catarrhal affections may be combated by hygienic measures. Syphilis is the only specific disease really transmitted to the offspring, and tuberculosis in extremely rare instances. Consumption is hereditary only in the sense that the tendency to this infection, or rather a feeble power of resistance, is so, but it may be met by early removal to the best hygienic surroundings. **Tuberculosis is acquired**, the bacilli usually imbibed by infants from the milk of tuberculous cows, and inhaled by adults from the dust of the dried sputa of consumptives.

PART II

HEALTH OF THE HOUSE

CHAPTER VII

Sites for Dwellings

STIFF clay soils are cold and damp from the accumulation of water on the surface, and the evaporation of the the greatest part. Chalk, sand, and gravels, on the contrary, by absorbing most of the rainfall, leave less to evaporate and are warmer and dryer, provided they are deep enough, or by the inequalities of their surface, allow the water to run off and collect in rivers. Shallow low-lying gravels, especially near rivers, may however, be water logged, and in such situations a house standing on clay may be drier than one on gravel. Indeed, Pettenkofer has wittily, but truly, said that "change of air" generally means "change of soil."

In choosing a site for a dwelling all these considerations may be taken into account, as well as the obvious ones of exposure to the sun, to east and north winds or the reverse, but there are a few other special points which deserve to be mentioned.

Hollows, whether on low or high land, should be avoided, as well as the bottom of a valley between hills

rising on each side, and too close proximity to the foot of a hill. Again, when a house is built on a hill-side, the ground should not be dug out so that a cliff rises immediately behind. In such a position the excavated soil should be used to form a terrace, with a trench in rear of the building; and the soil beneath and around must be drained. When a hill is composed of gravel overlying clay, it not unfrequently happens that springs are found at the outcrop or line of junction; and a house built at that particular level will be damp, while those above on the gravel or below on the clay are dry.

Trees may afford valuable shelter, not only from cold winds but from fogs, but it is not generally advisable to have them close around a dwelling, at least in large numbers, since they impede the free circulation of the surrounding air and tend to confine evaporation beneath their shade. In hot climates brushwood should be cleared, but houses are advantageously placed under the shadow of a few spreading trees.

Aspect.—Of the three requisites of a healthy house the construction is most completely in one's power; in the country one may choose the position, and in towns one may improve a site naturally bad by drainage and by damp-proof foundations; but as regards aspect we have mostly to take it as we find it, and the opposite sides of a street can scarcely enjoy the same advantages. In the country a house may be sheltered from cold east or north-east winds by trees, if not already protected by rising ground, but otherwise the more open the situation the better. Exposure of each side of a house in succession to the rays of the sun tends to keep the outer walls dry, to warm it in winter, and in summer to aid the ventilation by the variations it induces between the internal and external pressure of the air. The north wall may be made with advantage a dead one, and then drain ventilating pipes and soil pipes may safely be carried up it. But chimneys carried up a north wall, being warmed

with difficulty and apt to smoke, should not project, but be built inside the house. The north or north-east aspect is the best for larders which must be kept cool, and for libraries, laboratories, and workshops, where a diffused light is desirable. Streets running north and south are preferable to those running east and west, since the latter do not receive the sun's rays through their whole length for more than six months in the year and even then on the south side only obliquely before 6 A.M. and after 6 P.M. In laying the plan of a town the greatest amount of sunshine would be enjoyed by the greatest possible number of houses if the streets all ran obliquely, *i.e.*, north-east and south-west, and north-west and south-east. "Cul de sacs," or streets with closed ends, are objectionable, and courts with narrow openings still more so. Streets and spaces in rear of houses should be wider than the houses are high, and frequently broken by cross streets opposite to one another. Squares in like manner should be perfectly open at the corners. If the price of land necessitate the use of basement rooms it should only be by day, there should be a wide area, and the sills of the windows ought not to be below the ground level. Attics with slanting ceilings and dormer windows are cold in winter and intolerably hot in summer, and if without chimneys are most unhealthy.

In conclusion two general rules may be given which should never be neglected. To visit a proposed site in the evening when the conditions are most favourable to the production of common or radiation fogs, and except where the soil and configuration of the site are such as to allow of the freest natural drainage always to drain the subsoil before building. To which we may add a piece of advice to dwellers in towns. If the site be advertised as gravelly, be sure that the gravel has not been dug out and sold and the hole filled up with so-called "made soil," in other words the emptyings of all the dust bins in the district.

Composition and Impurities of Air

Air is a mixture of oxygen and nitrogen in the proportions of about 21 per cent. of the former to 79 per cent. of the latter. It is not, like water, a chemical compound, into which the constituent elements enter in multiples of certain fixed combining proportions, and in which all traces of the properties of each are lost, but a mixture of uncertain and variable composition, and in which each element preserves all its own characteristic properties, independently of the others.

But from the action of a law by which gases (and liquids so far as they are miscible) tend to diffuse themselves in space, irrespective of their specific or relative gravity, the composition of the atmosphere is fairly constant, any local differences speedily disappearing. Currents produced by changes of temperature, whether in the form of wind in open, or draughts in closed spaces, aid the natural diffusion of gases in maintaining their uniformity of distribution.

From numerous analyses of the air in town and country, it appears that pure air consists in 1000 parts of—

Oxygen,	209 to 211	or a mean of	209·6
Nitrogen,	789 to 791	,,	790·0
Carbon dioxide,	·29 (day) and ·31 (night)	mean	·308, or say ·3 [1]

to which must be added a quantity of watery vapour in the form of an invisible gas, the possible maximum of which depends on the temperature, and ranges from 2·13 grains per cubic foot at freezing, to 10·98 grains at 80° F., two-thirds to three-fourths of these weights being usually actually present.

Traces of ammonia, organic matter, &c., are generally discoverable, as well as of other gases, &c., due to local circumstances, as CH_4, and CO_2 in the air of marshes ;

[1] In calculations of ventilation I have, however, followed the majority of text-books in giving the mean as ·4, an error perhaps on the right side.

HCl, SO_2, H_2SO_4, and suspended carbon and tarry matters in that of towns, and the neighbourhood of chemical works ; and suspended sodium chloride, &c., in the air blowing from the sea.

Ozone, an allotropic or probably a condensed form of oxygen, exists in the air of the country, but is destroyed in passing over populous towns, from its tendency to combine almost instantly with any oxidisable matters it may meet. It is largely formed during thunderstorms, and in a concentrated state has a peculiar odour, but when dilute can be distinguished from ordinary oxygen only by its power of liberating iodine from the iodides.

The so-called ozone papers intended to indicate its presence consist of strips of white bibulous paper charged with a solution of iodide of potassium and starch, which are exposed to the air in a position where they are protected from sun and rain, and the proportion of ozone is estimated by the colour produced by the action of the liberated iodine on the starch. Unfortunately, however, other bodies besides ozone act in the same way, and notably nitrous fumes, chlorine, and sulphurous acid, bodies which are most likely to abound precisely in those places where ozone is most constantly absent. Thus while in a course of observations conducted in concert by Dr. Tripe at Hackney, and Mr. Burge at Fulham, the former always noticed the strongest indications of its presence when the wind blew from the N., N.E., and E., and the latter when it came from the W., S.W., and S., and *vice versâ* of its absence ; the greatest discoloration of their papers was observed by each on the night following the landing of the Princess of Wales, when the air was redolent of fireworks !

The presence of ozone indicates the absence of oxidisable, and therefore of organic matters, and some other products of putrefaction, and is thus indirectly a proof of purity, but it is doubtful whether it is directly beneficial to animal life, and any measurable quantity is actually fatal, perhaps from its intense energy.

Ground air, which may be found in wells and excavations, and may be drawn up into cellars by the warmth of the rooms above, always contains a large proportion,

of carbon dioxide, commonly called carbonic acid. This gas may also be present in a dangerous or fatal amount in limekilns, and in brewery vats, but nowhere else is it likely to exist in the pure state in quantities injurious to health.

Coal gas escaping from broken mains may mix with the ground air, and drawn by the warmth of adjacent houses, enter the basements and lead to serious poisoning. In the severe winters of Germany, when the temperature indoors is much above that of the open air, such occurrences are not infrequent, and here, too, they may not be so rare as is commonly supposed. Some cases of gas poisoning have been speedily fatal, in others the symptoms have been mistaken for typhoid fever, until removal of the patient has been followed by rapid recovery. The distances to which gas may thus be carried underground are surprising, and it is important to bear in mind that for some time no smell may be perceived. The odour of coal gas is due to tarry matters which may be retained in the soil until it has become saturated and incapable of absorbing more, whereas the poisonous character of coal gas is owing to the presence of carbon monoxide (CO), which is perfectly devoid of smell. The so-called "water gas," much used in America as a substitute for, and in this country as an addition to, coal gas, contains a very large percentage of carbon monoxide, and escapes of such gas are especially dangerous to life.

Carbon Dioxide.—The importance of correctly estimating the proportion of this gas present in the air of rooms depends on the fact that it is the product of respiration and of the combustion of gas, &c., used for lighting, and occasionally of fuel, and that while it is thus formed at the expense of the oxygen, which is reduced to an equal extent, it is at the same time accompanied by other and far more injurious products, the amount of which bears a nearly constant ratio to that of the carbon dioxide; and the estimation of this gas being far more easy than that of the other impurities, or of the reduction of oxygen, it is conveniently taken as an indication of the extent of the deterioration.

The organic matter given off from the lungs and skins

of men and animals, even in perfect health, and still more in disease, is in the highest degree poisonous, and consequently "respiratory carbonic acid," or the quantity added to that originally present, is the special object of analysis.

Pure carbon dioxide is fatal when present in the proportion of 50 to 100 parts per 1000, and severe headache, &c., may be induced in some persons by 15 to 20 parts, though the air of soda-water factories often contains 5 to 10 parts per 1000, without any inconveniences being experienced by the workmen.

The "respiratory carbonic acid" is estimated by deducting the proportion present in the outer air, or what practically comes to the same thing, ·4 per 1000 from the total CO_2 found. Anything under ·2 parts per 1000 is not perceived by the sense of smell, and may be looked on as innocent and unavoidable ; ·2 per 1000 of this or a total of ·6 is therefore called the permissible impurity. When it exceeds this the accompanying fetid organic matters become perceptible ; ·4 is disagreeable, ·6 offensive, ·8 sickening, and the nose is not capable of distinguishing further addition. Any of these proportions may be found in ill-ventilated and crowded bedrooms, in the dwellings of the poor, and in places of public resort, of which numerous examples may be gathered from the works of A. Smith, Roscoe, Pettenkofer, and others. But yet higher amounts, as 3, 5, 7, and even 10 parts per 1000, have actually been observed by these chemists in schools, factories, theatres, and law courts. To the organic matter, and not as is popularly supposed to the heat or even to the carbon dioxide itself, are due the headaches, faintness, &c., so often felt in crowded assemblies.

To form a correct judgment of the degree of impurity as indicated by the smell it is necessary that the observer shall have been for at least the preceding half hour in the open air, for the sense of smell is so dulled by breath-

ing foul air of this kind that the occupants of the room are seldom aware of its state. In fact persons on first entering an overcrowded, ill-ventilated, and dirty apartment may be violently affected, while the regular occupants are not sensible of any inconvenience. The injury, ochlotic poisoning as it is called (ὄχλος = a crowd), is not less real for being unperceived. It induces a general lowering of the vital processes, impairment of nutrition, and loss of muscular strength; the blood becomes laden with effete matters from the diminished aeration; a craving for alcoholic stimulants in the form of ardent spirits follows on the nervous depression; and the subjects of chronic ochlotic poisoning fall easy victims to disease. These effects may be to a great extent counteracted by active exercise in the open air, and it is thus that sailors, whose sleeping accommodation is everywhere ill-arranged, agricultural and outdoor labourers, and the children in elementary schools, for the most part do not appear to suffer as much as might be expected; but it is more probably to this cause than to excessive mental strain that the breakdown of so large a proportion of female pupil teachers is owing, and it is impossible to over-estimate its influence in the physical deterioration and moral degradation of the poorest classes.

Thus the prevalence of "consumption" among tailors, needlewomen and till recently among printers, in fact, among all whose waking and working hours are passed in crowded, badly ventilated rooms, lighted for hours with gas or oil, was formerly ascribed to "breathing rebreathed air," but this is now known to be a remote or predisposing cause only, producing a lowered vitality and loss of resistance to infection by the spores of the tubercle bacillus inhaled with dust, whether in the workroom or elsewhere; and the great improvement that has taken place of late years in the construction and ventilation of factories, &c., has been followed by the best results.

QUANTITY OF AIR REQUIRED IN INHABITED ROOMS.

We have seen that the effects of respiration in rendering the air of a chamber unwholesome are due to the animal exhalations, and not, under ordinary circumstances, to the carbon dioxide *per se*, but that the CO_2 forms so trustworthy an indication of the amount of organic matters given off from the lungs at the same time that it is quite enough to determine the quantity of "respiratory" as distinguished from "initial carbonic acid." And for all practical purposes we may consider this respiratory carbonic acid as a constant quantity under given conditions, just as we know the amount of CO_2 generated in the combustion of a given quantity of gas, &c.

An average adult at rest adds to the air about ·6 of a cubic foot of CO_2 per hour, to produce which he abstracts the same quantity of oxygen. We have seen that "pure air" already contains ·4 parts per 1000 of CO_2, but since it would be manifestly absurd to demand that the air of a room should be always as pure as that of an open field (and the attainment of such a result would require a supply for a single man in a room containing 1000 cubic feet of 1,000,000 cubic feet of air per hour, in other words that the entire air should be changed 1000 times per hour, or once in 3½ seconds!), we must needs fix on some limit of permissible impurity. Now, the most delicate sense failing to detect any smell of organic pollution when the respiratory CO_2 does not exceed ·2 parts per 1000, we may safely consider this amount as innocuous, and set down as the limit of permissible impurity or of practical purity ·6 = ·4 of initial + ·2 of respiratory CO_2 per 1000 volumes = ·0002 per cubic foot of the latter.

Dr. de Chaumont devised a very simple formula for determining the volume of pure air requisite per hour to maintain this standard in any inhabited room, and conversely to determine the actual supply from the de-

gree of impurity ascertained to exist after a certain number of hours' occupation.

Let $p = CO_2$ in 1 cubic foot of pure air; P = amount emitted by each person per hour.

A = cubic feet of air introduced per hour, the same amount escaping by outlets; π the resulting or permanent impurity of the air.

$$\pi = p + \frac{P}{A} \qquad \text{or } A = \frac{P}{\pi - p}$$

$$P = \cdot 6\,;\ p = \cdot 0004\,;\ \pi = \cdot 0006, \text{ then}$$

$$A = \frac{P}{\pi - p} = \frac{\cdot 6}{\cdot 0006 - \cdot 0004} = 3000 \text{ cubic feet to be admitted}$$

per head per hour.

But p being practically constant may be neglected, and we may substitute ρ for $\pi - p$, the resultant or permissible impurity, as the case may be, due to the respiratory CO_2 alone.

The formula then becomes

$$A = \frac{P}{\rho}$$

Thus, to ascertain the amount of air to be supplied per hour for each person to maintain the practicable degree of purity, we have (assuming the individual exhalation of CO_2 to be ·6 cubic feet per hour)—

$$A = \frac{0 \cdot 6}{0 \cdot 0002} = 3000\,;$$

or, putting P at a higher figure, say ·7,

$$A = \frac{0 \cdot 7}{0 \cdot 0002} = 3500\,;$$

or, at ·8, $$A = \frac{0 \cdot 8}{0 \cdot 0002} = 4000.$$

If, under any circumstances, we are content with a purity

of ·3 per 1000, and assume the formation of CO_2 to be ·75 cubic feet per hour, we have

$$A = \frac{0.75}{0·0003} = 2500.$$

Again, the total CO_2 in a room was found after ordinary occupation to be 1·1 per 1000 = 0·0011 per cubic foot, that in the open being 0·0004; the respiratory CO_2 was therefore 0·0011 − 0·0004 = 0·0007, thus we have $A = \frac{0·6}{0·0007} = 857$ cubic feet per hour, as the volume of air per head delivered during the period of occupation.

The estimate of ·6 cubic feet as the quantity of CO_2 given off by each individual per hour is correct enough for practical purposes when we have to deal with average men, women, and children, at rest in ordinary dwelling-rooms; but since the production of CO_2 increases with the body weight, and is much greater during muscular exercise, it is certainly under the mark when we have to deal with strong men only, as soldiers, and still more so for men laboriously employed in workshops. For the former, at least ·7, and for the latter, ·8, ·9, or even 1·0 should be assumed. As men at work give off from 0·006[illegible] to 0·0115 cubic feet of CO_2 per pound body weight per hour, according to the hardness of their work, a man weighing 150 lbs. will require from 4500 to 8600 cubic feet of fresh air per hour; in short, under such circumstances the ventilation should be as nearly unlimited as possible. It has been noticed in mines that the men require not less than 6000 cubic feet per hour, and that with 3000 or even 4000 there is a serious falling off in the work done.

Again, the watery vapour exhaled by one man in one hour will raise the humidity of 500 cubic feet of air at 60° F. from 70 per cent. to complete saturation. To reduce this to 73 per cent. would require 3000 cubic feet of air at 50° F. If we add to this the vapour from lights, 3000

cubic feet will be found insufficient. Walls, ceilings, and floors are not impervious; doors and windows are not air tight; but the better the building the more need there is for special means of ventilation, at least of inlets corresponding to the chimney outlet.

Carbon dioxide diffuses itself well, but the organic matter of the pulmonary exhalations lingers in corners, and clings to curtains and furniture. Hence the importance of having few hangings, &c., in bedrooms and in rooms occupied by the sick.

Mere height in a room is of no advantage, unless the windows reach the highest part of the wall, or there are special outlets there, or in the ceiling, otherwise a deep stratum of hot and foul gases gathers between the ceiling and the level of the windows, whence it diffuses itself, and with its moisture and organic matter subsides on cooling.

In churches and public buildings with lofty naves or domes, not kept warm by gaslights as are the roofs of theatres, this cooling and descent of the foul air goes on continuously, any apertures for its escape acting as refrigerators only.

Allowance of Air for Lights

Gas, candles, and lamps of all kinds, except the electric light, use up oxygen, giving off water and carbon dioxide; and coal gas diffuses also several products of the combustion of sulphur, and unburnt gases.

These, however, do not bear any proportion to the intensity of the light afforded; indeed, as a rule, the better the light the less the deterioration of the air. For equal amounts of light, candles and oil consume more oxygen than gas, flat wicks more than round ones, and batswing burners than argands.

Every cubic foot of gas requires, for the proper dilution of the products of its combustion, 1800 cubic feet of air, since each cubic foot of good gas gives off two of carbonic acid, and ·2 to ·5 grains of SO_2. A common batswing or

Bray consumes three or four cubic feet of gas per hour, and therefore requires from 5000 to 7000 cubic feet of air ; in other words, is equal to from one to two full-grown men in its consumption of oxygen, and general deterioration of the air.

Gaslights may be made powerful aids to ventilation, but if such a special arrangement be not adopted, the use of those burners, which shut off from the air of the room receive their supply from without, and the products of whose combustion are carried off by a special channel, is strongly to be recommended. The Wenham and the regenerative burners of Siemens, Clarke and Thomas, with annular and downward and therefore shadowless discs of flame enclosed in a hemispherical glass, have great illuminative power, are perfectly motionless, and are capable of being shut off from the air of the room. Indeed, the ordinary practice of employing naked flames is scarcely less irrational or injurious than that of warming by braziers instead of fire-stoves and chimneys.

The popular prejudice against gas, though exaggerated, is not altogether groundless. For equal quantities of light, the CO_2 given off is less than with oil or candles, though the ease with which gas is obtained leads to a much more lavish indulgence. But gas always contains some sulphur, chiefly in the form of carbonic sulphide (bisulphide of carbon) CS_2, a body analogous to CO_2, which in burning is converted into CO_2 and SO_2. The latter, sulphurous acid, acts injuriously on pictures, the binding of books, and on colours or dyes in fabrics, as well as on vegetable life, though it is doubtful if in such small quantities it can have much effect on health.

When the pressure exceeds a certain point combustion is incomplete, the tarry matters to which the odour of gas is due, and the heavy hydrocarbons which give it its illuminating power are burnt first, while the less inflammable constituents escape into the air of the room.

The composition of coal gas varies much in different places, and at different times in the same place. The law takes cognisance of the illuminating power, and of the presence of sulphur compounds.

Prof. A. Lewes gives the composition of the South Metropolitan gas as :—

	Hydrogen,	47·9	Carbon Monox,	6·0
Illuminants.	Methane Series,	41·2	Oxygen,	0·5
	Ethylene Series,	3·5		
	Benzene Series,	0·9		

The candle power of the several hydrocarbons per 5 cubic feet of gas is approximately :—

Methane,	0·05	Benzene,	4·20
Ethane,	0·35	Toluene,	7·40
Propane,	0·56	Naphthalene,	9·90
Ethylene,	0·70		

The 0·9 of the benzene series is thus equal in illuminating power to 50 or perhaps 100 of the methane series.

The following figures taken from a table in an exhaustive discussion of the subject by the German Engineer F. Fisher show the cost, and the amount of heat and of CO_2 evolved by each of the principal means of lighting, the degree of illumination being the same in each case. To take the electric lights, the arc and incandescent, while neither yields any products of combustion, the former evolves, for every hundred German candles, from 57 to 158 units of heat per hour, and the latter 290 to 536 at a greater expenditure of horse power and cost. Again, comparing three forms of gas lamps, Siemens' regenerative burner, the argand, and the common batswing, the cost of these was found to be respectively, 8, 14, and 36 pfennings (100 = one shilling), the CO_2 given off 0, 0·46, and 1·14 cubic meters, and the heat 1500, 4800, and 12,150 units. Round wick petroleum lamps gave off 0·44 cubic meters of CO_2 and 3600 thermal units, while flat wicks gave nearly twice as much, viz., 0·95 cubic meters of CO_2 and 7200 units of heat for the same amount of light; while candles of all kinds, wax, sperm, stearin, and tallow, are twice as injurious and incomparably more expensive —a tallow candle thirty times, and a wax one sixty times, as a round wick petroleum or a Siemens gas light.

Dr. Carl Auer von Welsbach of Vienna brought out a gas light on an entirely new principle. Flames which, like the spirit lamp, Bunsen gas burner, and oxyhydrogen blow-pipe, are attended with complete combustion, evolve great heat, but are practically non-luminous. Candles, oil, and gas lights owe their luminosity to the presence in the flame for a time at least of unburnt and

incandescent particles of carbon, which if they escape ultimate combustion on reaching the air appear as soot. The lime light is obtained by introducing into the oxyhydrogen flame a piece of lime which, being indestructible, emits a light corresponding in intensity to the elevation of the temperature. Dr. Welsbach availed himself of the heat of the far less costly Bunsen burner to produce a flame of great brilliancy with a very small consumption of gas, and avoidance of smoke and waste. The burner is surmounted by an extinguisher-shaped wick or "mantel" steeped in a salt of zirconium. When first it is lighted the stiffening is consumed, and the incombustible skeleton alone remains, presenting the appearance of a motionless solid cone of light. The burners cost a few shillings, but the wicks last for many weeks or months, and can be renewed for a trifle. The cheaper substitutes for Welsbach's mantels are all inferior, but the "Kern" burner is an improvement on the Bunsen, requiring no chimney and lighting without explosion. Light for light, the saving of gas, as compared with the common nipple burner, is as much as 70 or 80 per cent., but nearly double the light can be had for half the quantity of gas.

Governors or *regulators.*—By fixing one of these on the house side of the meter a great saving—20 to 30 per cent.—is effected. They act by adapting the throttle of the pipe to the varying pressure. The gas companies insist on their use whenever they supply gas by *contract*—conclusive evidence of their economy for the consumer.

It may not appear evident at first sight, and it cannot be proved but by the differential calculus, that the same amount of ventilation, *i.e.*, the same supply of fresh air, is required in the largest as in the smallest room—the only difference being, that in the former the period at which the point of permissible impurity is reached is longer delayed, but when it is reached, the same volume, be it 3000 or any other quantity per head per hour, must be supplied. Large rooms, however, possess one advantage over smaller, that the change of air is effected with less perceptible motion—that is, less draught. For example, the admission of 3000 cubic feet per hour into a room of 1000 cubic feet involves a complete change of air in twenty minutes, but in one of 10,000 feet of cubic space only once in 200 minutes, or for four occupants every five

and every fifty minutes respectively. The former would be felt distinctly, the latter would be unperceived.

The following cubic spaces as fixed by law or regulations have been calculated on the foregoing data, and adjudged for the respective classes of dwellings and institutions. It will be seen that in some cases, as common lodging-houses, a far lower degree of purity has been deemed admissible, while in others, as hospitals, ampler air supply and cubic space is considered necessary for the well-being of the inmates. The sick, especially fever patients, cannot have too much. Regard is also had to the number of hours during which the occupants of a room are exposed to the influences of the comparatively or positively impure air, as for the two or three hours of school work or the whole night long.

CUBIC SPACE PER HEAD.

Common lodging-houses . . .	300	cubic feet.
Poor-Law for healthy persons . .	300	,,
,, for the sick . . .	850 to 1200	,,
Barracks (too little)	600	,,
Army hospital wards	1200	,,
Non-textile work rooms . . .	250	,,
Canal boats	60 (!!)	,,
London board schools . . .	130*	,,
(10 square feet floor space, 13 feet height)		
Education Act (8 square feet, 10 height)	100*	,,
Registered lodging-houses, rooms occupied		
by day and night	400	,,
By night only	300	,,

Where large numbers of persons have to occupy a single room, as in wards, dormitories, and schools, the question of floor space becomes important, *i.e.*, we have to consider superficial as well as cubic measures. Any amount of cubic space may be obtained by increasing the height of a room, but since the diffusion of gases is not

* Far too little, even for two or three hours. It ought not to be less than 240, the allowance in Canadian schools.

an instantaneous process, such additional height is of little, if any, advantage to persons packed on the floor. Really low rooms, *i.e.*, rooms under nine feet, are decidedly objectionable, but in a crowded place no great benefit is attained by a greater height than fourteen feet. The animal exhalations especially do not diffuse, but hang about where the air is stagnant, as it is in the midst of a crowd. It would be well if the regulation space, insufficient though it be, required in schools were always to be had in churches.

The following is the floor space per bed in several hospitals:

St. George's .	70 sq. feet.	St. Thomas' .	112 sq. feet.
Herbert (Chatham)	99 ,,	Guy's . .	138 ,,
Netley . .	103 ,,	New Hôtel Dieu	104 to 110.

Fever hospitals, 150 to 300 square feet.

As a general rule hospitals without a medical school should give 100, those with clinical classes 100 to 150, fever 150 to 300, and freer ventilation; lying-in hospital 200, and the most ample supply of fresh air; infirmary (workhouse) wards used by day and night 70 to 80, and those used at night only 50 square feet per bed.

Nature and Detection of the Impurities in the Air and their Effects on Health.

The composition of the atmosphere, *i.e.*, the open air, is as regards the proportions of oxygen and nitrogen remarkably constant, the percentage of oxygen never exceeding twenty-one, even in the open country, nor falling below twenty in the most crowded streets of cities. The extremes observed by Dr. Angus Smith were 20·99 on Scottish mountains and 20·179 in the closest streets of Manchester; in London, 20·95 in Hyde Park, and 20·857 in a densely peopled part of the East End.

The carbonic acid is subject to much greater variations.

Dr. Smith found in London parks ·0301, and in the City ·0413 and ·0428, with an average of ·037; the average in Glasgow ·0502, and in Manchester ·0403, but during fogs ·0679.

There is also a variable amount of organic matter, which collected in water yields "albuminoid" ammonia by Wanklyn's process, the actual quantity depending on the movement or stagnation of the air.

Marsh air contains an excessive amount of CO_2, as much as ·6 or ·8 per 1000 volumes, also organic matter; "marsh gas," CH_4, and sometimes H_2S, formed by the reducing action of organisms on sulphates, also ammonia, and free hydrogen, and according to some PH_3.

Much has been written about the dangerous impurities present in the air of graveyards, but unless burial be improperly performed or the soil and site most ill-chosen, these are imaginary. Fleck, Pettenkofer, and others sought in vain for compounds of ammonia, sulphur, &c., and the only gas they found in excess was CO_2.

The case is quite different with the air of vaults and crypts in churches, where bodies are deposited in coffins of any kind, but are not exposed to the disintegrating action of the "living" earth.

Under such circumstances there is putrefaction rather than decomposition, fœtid, poisonous gases are evolved that no soldering or cementing can wholly confine, and which would lead to an explosion if they did; there is no reason to believe that all pathogenic microbes, especially the most virulent anaërobes (not requiring air) are destroyed, and as Prof. Selmi has shown, alkaloids and other chemical products are formed rivalling or realising in their intense toxicity the wildest traditions of mediæval crime.

Interments in churches should be absolutely prohibited, as dangerous to health and relics of a barbarous superstition.

The air of sewers contains hydric sulphide, ammonium sulphide, gaseous hydro-carbons, &c. Sulphur compounds are present with other impurities in the holds of ships. In mines we find the CO_2 of ground air generally, and

the products of the combustion of lights, of respiration, and of explosives used in blasting. That of factories contains the impurities incident to all rooms where human beings are congregated and lights are burning, together with gases and vapours produced by the various manufacturing processes.

The consideration of these belongs rather to the department of noxious and unhealthy trades ; but we may here remark that lead, arsenic, mercury, phosphorus, and the fumes evolved in brassfounding, exert toxic effects peculiar to each, whether in the form of dust or of vapour ; and acid, ammoniacal, sulphurous, and nitrous fumes act as chemical irritants on the mucous membrane of the respiratory passages ; but the merely mechanical irritation of suspended particles—in common language, dust—whether mineral or organic, plays perhaps the most important part in the production of lung diseases.

Tuberculosis, as we shall see later on, is undoubtedly an infectious process, but every other imaginable form of bronchial and pulmonary irritation, catarrhal, inflammatory and destructive, in short, asthma, bronchitis, and consumption of every kind except the tubercular, is caused by the inhalation of dust in textile manufactures, knife and needle grinding, stone-working, button-making, glass-grinding, &c., and these conditions are specially conducive to tubercular infection.

Carbon dioxide (pure), if present in less proportion than 10 parts per 1000, produces no appreciable inconvenience or effect on health. With 15 to 20 parts many persons experience headache, giddiness, feeble action of the heart, and quickened respiration ; 30 to 50 act thus on all persons ; and 50 to 100 parts per 1000 are sooner or later fatal. The action of CO_2 in gradually increasing quantity is that of a narcotic poison inducing deep sleep and insensibility to pain. Carbon monoxide (CO) is formed by the combustion of carbon in an atmosphere of the dioxide ($C+CO_2=2CO$) as on the surface of a charcoal stove not exposed to draughts. It is intensely poisonous, displacing oxygen in the red blood corpuscles, causing asphyxia, and paralysing the nervous centres of cardiac and respiratory action. It is the monoxide probably

that plays the chief part in poisoning by charcoal braziers; and in experiments on animals, ·5 per cent. has been found to produce poisoning, and 1 per cent. fatal consequences; death is, however, usually caused by the combined action of CO_2 and CO. The so-called "water gas," now very generally added to coal gas, contains a large amount of CO, which in combustion is oxidised into CO_2; but, if escaping unburned, may easily prove fatal.

Hydric sulphide (H_2S), commonly called sulphuretted hydrogen, occurs in mines and excavations from the decomposition of iron pyrites (ferrous sulphide, FeS). The symptoms of acute poisoning are (1) narcotic, or (2) convulsive; those of more chronic poisoning are great loss of strength and of appetite, anæmia, a tendency to boils, diarrhœa, &c.

Marsh Gas, methane (CH_4), breathed in small quantities seems to act injuriously on the health. In large amount, as in coal-pits, it produces vomiting, convulsions, stertor, and death.

Air rendered impure by respiration suffers a loss of oxygen, which is exchanged for CO_2, and contains a large amount of fœtid organic matters exhaled from the lungs. The symptoms of acute poisoning, as observed in the Black Hole at Calcutta, the prison in which 300 Austrian soldiers were confined after the battle of Austerlitz of whom 260 died, and the steamer *Londonderry*, are not those of pure asphyxia or narcotism, *i.e.*, not due solely to the loss of oxygen or to the excess of carbonic dioxide, but in great part to the organic matter. The survivors suffered from febrile symptoms, boils, &c.

The symptoms of chronic poisoning from constant occupation of ill-ventilated apartments have been already alluded to as ochlotic poisoning.

Mephitic poisoning is the term applied to poisoning by the mixed impurities emanating from fæcal matters in a state of decomposition, sewer gas, &c., among which are NH_3, H_2S, $(NH_4)^2$ S, CO_2, and organic matters. Acute cases are rare, but in them vomiting, purging, headache, prostration, and convulsions, have been observed. Chronic

cases are, on the other hand, more frequent than most persons imagine, and are marked by vague symptoms of malaise, gastric and intestinal derangement, headache, slight cough, tendency to boils, sore throat, &c., the cause of which, viz., the access of sewer gases, is seldom suspected. Under these circumstances specific diseases as enteric fever, diphtheria, erysipelas, &c., are frequently met with.

Examination of Air

Detailed descriptions of quantitative chemical analyses do not come within the scope of this work, but we may shortly state that organic matters are estimated by passing the air through water, and subjecting this to Wanklyn's ammonia process. Gaseous impurities also are arrested by water, and estimated by ordinary methods applied to the solution.

Estimation of Oxygen.—The absolute weight present in a given volume of air varying as the pressure must be less by 10 to 20 per cent. on high plateaus than at the sea level. But the relative deficiency observed in the streets of cities is scarcely perceptible, and even that in crowded, ill-ventilated rooms requires for its determination so much greater technical skill than does the excess of CO_2 that it is rarely undertaken even by experts. Still, questions being occasionally set, I may state that of the methods described in text-books of chemistry those based on reduction in volume of air, (1) exploded with excess of hydrogen in a eudiometer by an electric spark, or (2) through the absorption of the oxygen by a solution of potassium pyrogallate in a graduated tube over mercury, are not sufficiently accurate. It would be best to give that in which a known weight of air is passed through a combustion tube filled with copper filings, previously weighed and raised to a red heat, when the increase in weight due to the oxidation of the copper represents that of the O in the air examined, and the analysis may be completed by weighing the N received in an exhausted glass globe, the CO_2 intercepted by HKO, and the water vapour by $CaCl_2$ or H_2SO_4.

Estimation of Carbon Dioxide in Air.—But for practical purposes the determination of the carbon dioxide, which if respiratory is a measure of the organic matter that accompanies it, and the microscopical examination of suspended matters, are all that are generally necessary. To determine the CO_2, fill a large bottle of $4\frac{1}{2}$ litres, or a gallon, with water, and empty it in the place the air of which is to be examined, then introduce 60 ccs. of a standard solution of lime or baryta, agitate well, and

let it stand for six or eight hours if lime, or for one if baryta be used.

[A standard solution of oxalic acid is made by dissolving 2·25 grams of the crystals in a litre (= 1000 grams or ccs.) of recently distilled water, so that 1 cc. will exactly neutralise 1 milligram (·001 gram) of lime.]

After the lime water has been long enough in contact with the air to be examined, 30 ccs. are withdrawn and the acid sol. added, until testing with tumeric and litmus papers indicates exact neutralisation, and the same is done with 30 ccs. of the lime water itself. The difference between the number of ccs. of acid solution required to neutralise the lime water before and after exposure to the air gives the milligrams of lime thrown down by the CO_2 in the air.

Multiplied by 0·795, the quotient is the ccs. of CO_2 in the volume of air, *i.e.*, the cubic capacity of the bottle, less the 60 cc. The factor 0·795 is calculated from the ratios between the equivalents of CaO and CO_2, and between the weight and volume at zero of the latter.

Correction for Temperature.—If, as is usually the case, the temperature be above freezing, the degrees F. – 32 × ·002 must be added to the result, or if below, must be deducted.

Correction for Pressure is rarely called for unless the site be very elevated, then

$$\left\{\begin{array}{c}\text{As standard height of}\\ \text{Barometer}\\ (29{\cdot}92\text{ in.}=760\text{ mm.})\end{array}\right\} : \left\{\begin{array}{c}\text{observed}\\ \text{height of}\\ \text{Barometer}\end{array}\right\} :: \left\{\begin{array}{c}\text{actual}\\ \text{capacity}\\ \text{of bottle}\end{array}\right\} : \left\{\begin{array}{c}x\text{ or corrected}\\ \text{capacity.}\end{array}\right\}$$

Microscopical Examination.

To determine the nature of the suspended particles, from a merely qualitative point of view, the dust may be collected wherever it is deposited. If it is desired to ascertain what matters are diffused through the air, and the quantity in a given volume, some form of aeroscope must be employed. The air is driven by an aspirator or a bellows of known capacity on a glass disk moistened with glycerine, to which the solid particles, inorganic and organic, adhere, and their nature is learned by microscopical examination. But this method does not inform one whether the germs, bacilli, micrococci, and spores are living or dead. To ascertain this Koch substituted for the glycerine a film of semi-solid solution of gelatin in a cultivating fluid. Every living germ then becomes a colony or focus of bacterial developments, the growing organisms mostly liquefying the gelatin around them, and forming circular or ovoid cavities containing fluid, in which they undergo proliferation, while the inorganic or dead particles produce no effect.

Summary of Chapter VII.

The best site for a dwelling is a deep pervious soil, as sand, gravel or chalk, in which the ground water is far below the foundations, or an impervious rock, off which the rainfall runs without being absorbed. Clays are cold and damp because the water stands on the surface, evaporating slowly, or sinks in but a little way. But permeable soils with the ground water only a few feet from the surface and rising and falling from time to time are the worst; and clays may be made dry and safe by surface drainage and paving. Hollows, the feet and sides of hills, and the lines of natural subsoil drainage are all damp; when houses are built on these, surface and storm waters should be diverted by trenches from soaking under the houses. Trees are useful to screen from cold winds and hot sun, evergreens in the former case and deciduous trees in the latter, but they should not impede ventilation, light or evaporation. In towns, closed squares or courts, blind streets, or streets less in width than the height of the houses, are bad, being deficient in light and movement of the air. **The foundations** should always be covered with concrete, or in very damp sites built on arches, and in all cases well ventilated, the walls being built with damp-proof courses and faced with cement or surrounded by deep open areas to ensure dryness.

The composition of air is roughly 79 per cent. nitrogen and 21 per cent. oxygen, with 0·04 carbonic dioxide, and water-vapour 2 to 10 grains per cubic foot according to the temperature, &c. In the open country and on the sea some of the oxygen exists in the form of ozone, O_3 instead of O_2. Ground air, that in the interstices of the soil, contains a very large proportion of CO_2, formed from the organic matter. **The air of occupied rooms** contains large quantities of CO_2, not enough to be injurious in itself, but being the product of respiration it is an index to the poisonous organic matter given off with it; it is partly also the product of the combustion of lamps, and, if of gas-lights, is accompanied by CO, by sulphur compounds, &c.

All CO_2 over the natural 0·4 per 1000 is called respiratory, and 0·2 per 1000, *i.e.*, a total of 0·6, being quite imperceptible to the smell is known as permissible impurity. **In ill-ventilated rooms** 0·4, 0·6 and even 0·8 are often present and are recognised by one coming in from the open air as close, disagreeable or sickening, but not perceived by the occupants. Even higher amonnts as 3, 5, or more per 1000 have been found in schools,

law courts, common lodging-houses, &c. **Excess of respiratory CO_2**, *i.e.*, of the accompanying impurities, causes headache, languor and low health.

An adult at rest gives off 0·6 cubic foot of CO_2 per hour, and at work 0·7, 0·8 or even 1·0 cubic foot.

To calculate the amount of fresh air required to be supplied per hour to maintain any degree of purity in a room occupied by a given number of persons, or given the supply to find the number of persons who may safely be allowed, the following simple formula may be used :—

$$A = \frac{P}{\rho}$$

A being the cubic feet of air supplied per hour.

P the volume in cubic feet of CO_2 given off by each person per hour.

ρ the permissible impurity under the circumstances, whether the ideal 0·0002 (*i.e.*, 0·2 per 1000) or more.

P will in like manner be 0·6, 0·8 or 1·0. But an additional volume of air is needed to dilute the water-vapour also exhaled.

Allowance must be made for lights, based on the O required in the combustion of the illuminant into CO_2 and H_2O, and with gas of the S into SO_3. Thus each cubic foot of gas requires 1800 of air per hour to dilute its products. **Electric lights** give off less heat than any others and no products of combustion. Light for light, **gas** and **petroleum** are less costly and deteriorate the air less than any **candles**, and of all gas burners the Welsbach gives the most light with the least consumption.

The **cubic space with good ventilation** desirable for each occupant of a room is 1000 cubic feet. In common lodging-houses the legal minimum is 300, the 100—130 permitted in elementary (Board) schools is grossly insufficient. In hospitals 2500 to 5000 are given. **Impure air** depresses the muscular and vital powers, and disposes to infectious and other diseases, as does sewer air, but with a more directly injurious effect.

The estimation of CO_2 in air is effected by shaking it up with a solution of quicklime or baryta and calculating the CO_2 absorbed by the alkali lost, which is known by the oxalic acid required to neutralise that which is left. The result being further corrected for barometric pressure and temperature.

Air may be examined also bacteriologically.

QUESTIONS ON CHAPTER VII.

1. Explain in detail why it is necessary to change the air of an inhabited room. 1884, E.

2. How are soils classified for hygienic purposes? What are the most healthy soils? Why is it important that the soil under houses should be drained? 1884, E.

3. How is the amount of CO^2 in the air ascertained? Of what use is the information thus obtained? 1884, A.

4. What is known as "the limit of permissible impurity"? How has it been ascertained? What are the methods of examining the state of ventilation of a room? If the CO^2 in the air of a room is 0·75 per 1000 volumes (that in the outer air being 0·4), and there are five persons in the room, how much air is entering the room per hour? 1884, H.

5. What is the normal composition of the atmosphere? How is it affected by the respiration of human beings? How much fresh air is necessary for each person per hour, and why? 1885, E.

6. What are the methods for examining the different suspended matters in the air? 1885, A.

7. What are the differences between the air of the country and of towns? What is the importance of these differences? 1887, E.

8. What test is used for the detection of ozone in the air? Explain its action and state the errors to which it is open.

9. What is the composition of expired air, and why is it unfit to be breathed again? 1888, E.

10. How is air vitiated by respiration? How many persons may be allowed to sleep in a room 12 feet long, 8 feet broad, and 10 feet high? 1889, E.

11. What are the effects of gas and oil lamps on the air of a room, and how much fresh air must be provided for each ordinary gas jet over and above that for the occupants in calculating the ventilation?

12. How much CO^2 is exhaled per hour by a man at rest and in active work? Calculate from this how much fresh air is required per hour, and per head, under each of these conditions to keep a room adequately ventilated? What relation does cubic space bear to ventilation? 1892, H.

13. How often can the air of a room be renewed without discomfort in warm and in cold weather? Illustrate by

examples the bearing of this on the relation of the number of occupants to the cubic space of a room.

14. How would you detect the presence and determine the amount of CO^2 in air? 1892, A.

15. In what way do soils affect health? Explain what is meant by "ground air" and "ground water." What influence have these on the healthiness of a site? 1892, H.

16. What is the difference in composition between atmospheric and ground air? What are the special characters of the air of vaults and of some wells? How may ground air be drawn into houses, and how should this be guarded against?

17. What influence do the rise and fall of the ground water and variations in barometric pressure exert on the movements of the ground air? What is the explanation of so-called "blowing wells"?

18. Why does the air vary in density and volume at different temperatures? What bearing has this on ventilation? 1894, A.

19. How do you know that air is a mechanical mixture of gases, and not a chemical compound? 1895, A.

20. What are the best sites for houses, and how are they influenced by surrounding objects? 1895, E.

21. What is the composition of ordinary coal gas? What the nature and amounts of the impurities that it yields to the air of rooms? Apply these facts to the ventilation of rooms thus lighted. 1895, H.

22. What is the composition of the so-called "water gas"? How is it made? Why is it so extremely poisonous, and what special danger attends its use alone or mixed with coal gas?

23. Compare coal gas and "water gas" as illuminants and as sources of heat. Is the characteristic odour of coal gas essential, and why is it sometimes absent from gas escaping from underground mains? Why do cases of gas poisoning from these escapes occur more frequently during cold winters?

24. What is acetylene, and how is it made? What its value as an illuminant? What special dangers attend the use of portable acetylene lamps?

25. What is the essential principle of "slow combustion" stoves, and why are they, especially those of the "tortoise" type, peculiarly dangerous to health? Why, too, are charcoal laundry irons and charcoal braziers more hurtful than "gas irons" and portable gas stoves?

26. How do the physical characters of the soil affect the health of those living on it? 1900, E.

27. Comment on Pettenkofer's saying, "we do not go for change of air, but for change of soil."

28. What is the significance of organic matter in the air? How does it affect the problem of ventilation, and how is the amount present usually determined? 1900, H.I.

29. What do you understand by "made soils"? How do they affect the healthiness of dwellings erected thereon? 1900, E.

30. What impurities are found in the air in the neighbourhood of brickfields? 1900, E.

31. What is meant by the "diffusion of gases"? How does it affect the question of ventilation? 1898, E.

32. What precautions should be taken to secure the healthiness of a site for a dwelling house to be erected on (*a*) the side of a clay hill, (*b*) fenland, and (*c*) a sandy soil containing springs? 1898, E.

33. Under what conditions may a clay site be dryer than, and preferable to one on sand or gravel?

34. How may the amount of oxygen in the air be determined?

35. How may a damp house be rendered dry (*a*) when the damp rises from the ground, and (*b*) when caused by rain beating on the walls?

36. In what circumstances are trees around houses advantageous, and in what detrimental to its healthiness? When should the preference be given to evergreens and when to deciduous? What harm may trees planted in streets effect?

37. What are the constituents of the smoke from coal fires that act injuriously on (*a*) the health of man, (*b*) vegetation and (*c*) limestone and iron work in buildings?

38. What substances, other than those common to all coal smoke, are given off from the chimneys of different factories? Does "smoke consumption" provide a remedy, and if not what means may be employed in each case?

39. The oxygen in the atmosphere is a fixed and limited quantity. How is it maintained, notwithstanding its constant removal in the respiration of animals and the combustion of fuel and illuminants?

CHAPTER VIII

VENTILATION

IN a previous section we described the composition of the atmosphere, the changes produced in the composi-

tion of air in closed spaces by animal respiration and combustion, the effects of impure air on health, the amount of air required to be supplied to the occupants of a room in order to maintain it at a relative degree of purity, as well as the cubic space per head necessary to render such renewal of the air practicable without an unpleasant sensation of movement, or as it is called, the production of draughts. The means and appliances for effecting this constant and agreeable change or renewal of the air of a room form the subject of the present section, viz., ventilation.

All ventilation, whether so-called natural or artificial, is effected by availing ourselves of the movements produced in large volumes of air as the consequences of different and varying densities of contiguous masses, and these differences are themselves dependent on differences and changes of temperature. The thermometer is said to indicate the temperature of the air and the barometer its weight. This is true enough for any given locality and moment of time, but the variations of the barometric readings are indirectly brought about by changes of temperature over wider areas.

The barometer is in fact a balance, having in one scale a column of the atmosphere, and in the other one of mercury over which is a vacuum, the height of the mercurial column above the level of the mercury on the other side representing the weight of a column of the atmosphere at that particular time and place. Several corrections of the apparent reading are required on account of the expansion of the mercury and scale, and to facilitate comparative observations by bringing all under similar and uniform conditions of altitude and temperature, but these need not be considered here.

The *mean* weight of a column of the atmosphere at the freezing point and sea-level is equal to that of a similar column, *i.e.*, of one having the same sectional area, of mercury thirty inches (760 mm.) high, that is, it exerts

a pressure of 14·7 lbs. on the square inch. Under such circumstances a cubic foot weighs, when dry, 566·85 grains.

Air, like other gases, expands with heat, at the rate of ·00203 of its volume for each degree F., or ·00367 for each degree C. Consequently warm air is lighter than cold, and the barometer will indicate this by falling. Again, water vapour is lighter than air—this may seem a paradox to those who associate the idea of visible steam with vapour, but the vapour we are speaking of is dry, in fact, is water in a gaseous state.

Air, as we have seen, is a *mixture* of four volumes of nitrogen, atomic weight 14, and 1 volume of oxygen, atomic weight 16. Each volume, therefore, is represented by $\frac{4 \times 14 + 16}{5} = 14{\cdot}4$, while water is a *compound* of 1 volume of oxygen $= 16$ and 2 volumes of hydrogen, and, like compound gases, occupies but 2 volumes, each being represented by the weight $\frac{16+2}{2} = 9$. A volume, *i.e.*, 11·2 litres of air therefore weighs 14·4 grams, and one of water vapour only 9 grams.

To sum up then, cold dry air is the heaviest and warm moist air the lightest possible arrangement, and it is thus that the barometer rises during dry easterly and sinks during damp westerly winds, that is to say, in Europe.

The total weight of the atmosphere must always be the same, but the density, and therefore the weight, vary with local circumstances, the decrease over one area being compensated by an increase over others. When the air over one large area is warmed it expands and rises, colder and consequently heavier masses of air over adjoining areas rushing in to take its place. Such is the causation of those movements of the air over wide regions which we call winds. The successive exposure of each part of the earth's surface to the rays of the sun

following on the diurnal revolution of the globe, together with the constant difference of temperature at the equator and the poles ; further, the influence of the distribution of land and water, having different radiant and absorbent powers, and differently affecting the humidity of the air ; and lastly, the local effects of the cooling of the air impinging on mountain ranges—all contribute to the production of winds and rainfalls. Indeed, the air is rarely, if ever, at absolute rest, even over the most limited area.

The same movements of air, due to different temperatures and the consequent differences of density and pressure, are repeated on a smaller scale in the house. It is thus that the warm air ascends in the chimney when a fire is burning, its place being taken by cold air entering by doors and windows : and even in the absence of fires the air of an inhabited dwelling, protected by closed doors and windows from the wind, is usually warmer than that outside, and rises within the building. The staircase then forms a great central ventilating shaft, drawing towards itself currents from every opening, large and small, intentional and accidental, from around doors and windows, from the basement, and through the spaces between the boards of the floors ; and sucking up the ground air from the foundations and the foul air from waste pipes and closets. The warmer the rooms the stronger will be the suction exerted. Thus it often happens that the ill-effects of defective sanitary arrangements make themselves manifest for the first time when the cold weather of winter brings about the general use of fires, and the difference between the internal and external temperatures is greatest. Thus, too, we see the necessity for a free supply of pure air to the basements by means of air bricks below the level of the floors, and the advisability of still further obviating the ascent of the ground air by concrete or asphalt laid over the whole area on which the house stands.

Whenever a room is warmed by fires, lights, or the presence of human beings, the air expands, and the excess of volume escaping by the chimney, the equilibrium between the air inside and out of the room is disturbed, and the aforesaid circulation commences.

Montgolfier's Theorem

The formula for determining the rate of movement of the air under such circumstances is founded on the law of falling bodies, and is called Montgolfier's Law, from which other special formulæ have beeen deduced.

The velocity acquired by falling bodies is expressed by the formula

$$v = \sqrt{2fs}$$

where f= the initial velocity given to the body, and s= the space through which it has fallen.

For bodies simply let fall without any extraneous force having been applied, f is represented by the attraction of the earth or gravitation, which, in our latitude, imparts a velocity of 32·2 feet in the first second, or g= 32·2.

$2g = 64{\cdot}8$, and $\sqrt{2g} = 8{\cdot}2$, or for practical purposes 8, and $v = 8\sqrt{s}$.

Now fluids escape through an aperture with a velocity equal to that which a solid body would acquire in falling through a space equal to the difference in the height of the columns on either side, and the formula becomes $v = 8\sqrt{H - H^1}$.

But in applying this to the movement of air in ventilation we must introduce the different densities of air at different temperatures due to its expansion by heat, as ascertained by multiplying the difference of the temperatures into the coefficient of expansion, then let

v=velocity of ascending air in feet per second.
H=height of shaft in feet.

t = temperature in shaft.
t^1 = temperature of outer air.
a = coefficient of expansion of air =
·002036 for 1° F., or ·003665 for 1° C., and
$g = 32·2$ (or strictly 32·17).

Our equation then becomes theoretically[1]

$$v = \sqrt{2gHa\,(t - t^1)}.$$

General Morin's formula for calculating exhausting power of flues and shafts

$$V = C\sqrt{(T - T^1)\,H}$$
$$Q = V \times A.$$

In which A is the sectional area of the flue or shaft for exit of air.

H	„	height of ditto.
T	„	temperature in ditto.
T^1	„	temperature of external air.
V	„	velocity of air in flue.
Q	„	quantity of air passed along the flue in a second.
and C	„	a coefficient, constant for each flue, depending on its form, capacity, &c.

But in practice it is greatly reduced by the friction consequent on the size, form, and material of the channel which varies directly with the square of the velocity of the current, and with the length of the shaft, and inversely with its sectional area. Again, in a rough or sooty

[1] This is near enough for all practical purposes, but it may be well to note for more accurate calculations that while the "head" or difference in the pressure of the cold and warm columns of air was formerly assumed to be represented by the increase in height which a given column of cold air would acquire when warmed, it has, since the appearance of the third edition of Peclet's work on heat, been taken as the "shrinkage" or reduction in height which the given column of warm air would suffer in being cooled to the temperature of the external air: the two estimates standing to one another in the relation of interest to discount, for it is the cold air that drives the warm air upwards, not the warm air that sucks up the cold.

chimney the friction is so great that the velocity may not be more than half what it would be in one with smooth and clean sides. It is also greatly influenced by the impediments to the ingress of fresh air, as, *e.g.*, by open or closed doors, and the absence or presence of special inlets in the room.

Friction may be represented by a further and variable coefficient K.

To allow for the effect of friction it is usual to reduce this value of v by $\frac{1}{4}$, $\frac{1}{3}$, or $\frac{1}{2}$, for the coefficient of friction in smooth channels is represented by $\frac{1}{1 \times \text{Sin}^2\theta}$, ($\theta$ being the angle at any bend of the shaft or tube) apart from that due to the mere length or roughness of its surface.

The following are the numerical values of the sines of several angles and of their squares :

Sin. $30° = \frac{1}{2}$	$\text{Sin.}^2\ 30° = \frac{1}{4}$	$K = \frac{4}{5}$
Sin. $45° = \frac{1}{\sqrt{2}}$	$\text{Sin.}^2\ 45° = \frac{1}{2}$	$K = \frac{2}{3}$
Sin. $60° = \frac{\sqrt{3}}{2}$	$\text{Sin.}^2\ 60° = \frac{3}{4}$	$K = \frac{4}{7}$
Sin. $90° = 1$	$\text{Sin.}^2\ 90° = 1$	$K = \frac{1}{2}$

If the tubes be of considerable length though straight, $\frac{1}{3}$ may be allowed for friction.

Friction varies as the ratio of the perimeter to the sectional area, and with regard to the total resulting resistance it may be said to vary (1) directly as the length, (2) inversely as the diameter, (3) directly as the square of the velocity, and (4) with the nature of the inner surface as this is smooth or rough.

With low velocities, as in a soil pipe or drain ventilator, or a chimney without a fire, the loss of pressure and therefore of velocity may be taken as the natural or barometric pressure × sine of the angle which the pipe makes with itself; thus for a right angle the loss is not of a half but of nearly the entire force.

When, too, a channel undergoes a sudden and large increase of section, as when a pipe enters a room, all pressure is lost and that for the exit pipe must be provided and estimated independently.

From the fuller form of Montgolfier's, Professor De Chaumont constructed two other formulæ, giving

(1) The delivery (D) per hour in cubic feet by inlets and outlets, and

(2) The inlets and outlets (I and $O = \Phi$), or inlets only = I, in square inches required for a given delivery per hour in cubic feet (D).

$$(1)\ D = I \times 200\ (\sqrt{h\ (t - t^1)\ \times \cdot 002})$$
$$(2)\ \Phi = 100\ (\sqrt{h\ (t - t^1)\ \times \cdot 002})$$

The different expressions for time and space require a factor—viz., 200 or 100, which is thus obtained :—

$$\frac{\text{Seconds in an hour}}{\text{Square inches in a square foot}} = \frac{3600}{144} = 25$$

which multiplied into $\sqrt{2g}$, or $8 = 200$ for inlets alone, or 100 for inlets and outlets combined.

In practice, however, it is often better merely to multiply the area of the aperture into the velocity of the air as ascertained by an anemometer, and thus to obtain the *net* influx or efflux, no correction being then required for friction.

If the inlet and outlet be very near one to the other, the air may not be properly distributed.

Warm air may be admitted anywhere ; cold air only above the heads of the occupants of the room.

In arranging the position of the inlets and outlets, care must be taken to avoid the formation of stagnant spaces in the corners or middle of the room.

A common fireplace extracts 3 to 6 cubic feet per second, a strong fire 6 to 8.

Perflation is the term applied to the rapid and thorough renewal of the air of a room by means of opposite and wide openings as doors and windows. It should be always carried out at the close of each service in church, attendance in school, public assembly, &c., and in bedrooms every morning.

But with modifications the same method of literal ventilation is applicable to all crowded rooms or buildings where the precise degree of temperature is a secondary consideration. Such are stables, cowsheds, workshops, army huts, &c., and the annexed diagram of a hut with double walls and ridge, will serve to show how such a rough structure may be kept dry and wholesome, though crowded (Fig. 1).

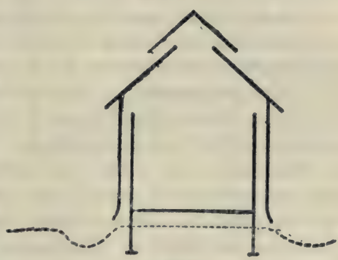


FIG. 1.

The ventilation of tents is somewhat difficult. While the canvas is dry air passes through pretty freely, and in the earlier stages of a shower the rain also as the occupants know too well. But when wet through it becomes impervious to air and rain alike. The German army tents are rendered perfectly watertight by a dressing composed of fat, resin, wax, and indiarubber, which also prevents the shrinkage. But ridge ventilators, "roof riders" as the Germans call them become the more necessary.

No aperture of inlet should exceed 48 to 60 square inches, but we must remember that in substituting smaller for larger openings we increase the loss by friction directly as the square roots of the areas; thus in dividing an aperture into four we admit only half as much air as before, so that to obtain the same amount of ventilation we must double the aggregate area, or in other words each of the four must have an area not less than half of that for which they are substituted.

In this and similar climates 24 square inches per head is a good allowance, though it must admit of being lessened in cold weather.

If for three or more persons, such an opening of 72 to 96 square inches would be too large for comfort, several

smaller ones must be substituted with the precautions above mentioned.

The best form of shaft or tube is the circular, with the internal surface as smooth as possible. Thus whether for ventilation only, or for chimney flues, glazed stone ware pipes permit of freer movement than brick flues of double their capacity. Angles, if unavoidable, should be as few and as obtuse as possible ; and on every ground the widest curves are to be preferred. In the majority of cases the mouth may be open, but if it be desired to prevent down draughts, and the entrance of rain, &c., some kind of cowl is required.

Advantage is taken on board ship of this action of wide-mouthed cowls, to ventilate the decks and engine rooms, some being kept with their mouths towards the wind, or the heads of steamships, to serve as inlets, and others in the opposite direction as outlets. Probably, however, the ventilation of ships, at present very defective, would be better attained by having the air tubes arranged horizontally, and in the length of the vessel, or best of all by the liberation of compressed air laid on by pipes to every compartment.

It may be necessary, especially with shafts or channels of inconsiderable length, to protect them by some valve, gauze, &c., from the entrance of blacks. Verity arranges a valve so that the dust and blacks impinge on and are arrested by a surface of water. Cotton wool, spread thinly on frames, is a most effective air filter ; but all such filters and gauze valves must be frequently renewed.

The air of a room should be completely changed three or four times per hour, *i.e.*, every 20 or 15 minutes ; a greater rate of movement cannot be borne if the air be cold, but may be scarcely perceived if it be warmed before admission. Hence the inestimable advantage of Galton's stoves, and similar arrangements, for heating the incoming air.

Thus assuming 3000 feet per hour to be enough for a

man at rest, *e.g.*, in a bedroom, sitting-room, or office, this can be supplied to one person in a room 10 feet every way, *i.e.*, containing 1000 cubic feet, by a complete change every 20 minutes, or three times in an hour; or if he use one or two common gas burners, not less than five or six times an hour. With a change every 15 minutes two persons would require, for comfort, a room, say 10 by 15 feet and 10 high. The art of ventilation consists in securing such a renewal of the air without the unpleasant sensation of movement called a draught; and in the greater ease with which this end is attained in spacious apartments their whole superiority consists, for their size does not render a lesser amount of fresh air per head necessary after the limit of permissible impurity has once been reached, which for one person in a room of 1000 cubic feet is in about three hours.

We may here explain the terms, natural and artificial, as applied to ventilation. The former is used when the movements are produced by differences of temperature in or out of the building. The forces of nature are made available for the purpose without any special appliances beyond apertures, shafts, &c.

In artificial ventilation, on the other hand, special contrivances, mechanical or other, are introduced for the exhaustion or propulsion of the air as a whole, independently of external and other circumstances.

Much has been written about the proper positions for the outlets and inlets respectively, and it is a popular observation that such rarely act long in the manner intended. The fact is, and it must never be forgotten, that external circumstances and the introduction of new internal conditions, or variations in those existing, may at any moment disturb the equilibrium and convert inlets into outlets or outlets into inlets. For example, in a room where in summer the balance is maintained, the lighting of a fire will convert all the other outlets into inlets to feed the stronger draught of the chimney. Again, the

rule that openings in or near the ceiling act as outlets is strictly true only of detached buildings, as schools or churches ; but in ordinary houses the exhausting power of the central shaft formed by the staircase is so strong, that, with the exception of the chimneys, and as experience too often proves, without even that exception, it converts every aperture into an inlet, those in or near the ceiling being low in relation to the staircase, though in the highest part of the particular room. Even the arrangements for carrying off the products of the combustion of gas-lights frequently fail, the current in them being overpowered by that of the fire in the chimney. A well-constructed chimney is at all times an efficient outlet, even in the absence of a fire, for the air of the room warmed by occupants, lights, &c., expanding, escapes thereby, and at once sets up a circulation in virtue of the unequal density of the air column in the chimney and outside of the room. Nay more, this difference between the temperatures of the external and internal air is not necessary, for the wind in passing across the upper aperture of the chimney sets up in it a secondary current; this aspiratory force of the wind being aided by the absence of internal friction and a free supply of air from below. The exhausting power is greatly increased by the action of a fire, and with or without one the up-draught is favoured by anything that tends to keep the chimney warm, and impaired by the reverse conditions. Hence the advantage of grouping flues in stacks, in which any one below which a fire is burning lends its warmth to the others, and the disadvantage of having chimneys on the outer, and especially the north or colder side of a house. Internal stacks are the best when practicable, and glazed stone ware pipes six or eight inches in diameter, set in the wall, or closely grouped with a little intervening cement, would be in every respect better than ordinary brick flues, and occupy far less room.

If the flue be very capacious, or the inlets insufficient

to balance the exhausting action of the fire, a double current will be set up in the chimney which will act as an inlet and outlet at the same time. This is a frequent cause of smoky chimneys, another being the inability of the fire to balance the exhaustion exerted by the staircase, on account of its shortness or the amount of friction caused by bends or bad workmanship, or from its being too much exposed to cold and wind.

The causes of smoky chimneys, and the remedies for this frequent source of annoyance and expense are matters in respect of which the general public are in a state of hopeless confusion, and at the mercy of tradesmen no less ignorant of the scientific principles which underlie them. Nor indeed do we know of any serious attempt at a rational explanation.

I would arrange the causes as :—

Internal.	*External.*
1. Excessive resistance from friction, bends, &c.	2. Loss of heat from exposure to cold.
3. Disproportionate (*a*) width or (*b*) shortness of flue.	4. Opposing force of stronger currents.
5. Deficient supply of air.	6. Entrance of eddies from above.

(1) Is exemplified in ill-constructed flues prone to deposits of soot, and those with abrupt bends or angles. (2) Is seen in chimneys in or built out from walls exposed to cold winds and rain, and in the naked pipe flues of stoves in outbuildings, &c. (3) In the width of some old kitchen chimneys, and in the shortness of those of upper bedrooms. (4) Commonly arises from communication of longer and shorter flues. (5) Is often brought about by successful efforts at the exclusion of draughts by rubber padding to doors and window sashes, and is frequently met with in the inner rooms of communicating suites, if they have not also doors opening into the passages ; and (6) when chimneys on the windward, especially the S.W. side of a house are overtopped by higher walls or roofs from which the wind is then deflected downwards, or in fact wherever they are exposed to eddies at different angles.

Tall, narrow-mouthed chimney-pots, especially if their apertures be protected by a cap, by increasing the height of the flue and permitting the extractive action of the wind will, if they do not exchange the existing conditions for those described under (2),

often suffice to overcome the difficulty as regards that particular chimney, but the result may be only to transfer the nuisance to another, thus Dr. Billings tells in his humorous way of a public building in Washington where were four rooms communicating one with the other, but only one of them with the corridor. When the fires were lighted No. 1 drew splendidly, No. 2 fairly, No. 3 badly, while No. 4 smoked furiously. After its chimney had been raised three or four feet above the others by a patent cowl it drew well, but No. 3 smoked even worse; it was then treated and cured, but No. 2 took to smoking. And when all were provided with cowls, and raised to the same level, No. 4 again smoked, and the business began *da capo*. Wall ventilators would, in the absence of doors, have supplied the air required for each chimney independently of the others.

Most persons seem to think that a cowl would cure any chimney of smoking if from among the embarrassing multitude of hideous forms they could but hit on the right one. Manufacturers claim for the so-called "Archimedean" revolving cowls the power of pumping or mechanically extracting the air from the chimney, and the deluded householder likes to see and hear it spinning merrily overhead. But no cowl can by any possibility exert any active force, so long as it is moved by the wind itself, and not like Blackman's fans by steam power.

FIG. 2.

The sole function of a cowl is to give free play to the aspiratory action of the wind, and to exclude down draughts and eddies, but it cannot offer any impediment to a reversal of the normal draught induced by opposing currents or disturbances of the atmospheric equilibrium within the building. Revolving hooded cowls, so long as they respond to every shifting gust, may be of some use, but failing to do so they aggravate the evil, acting like those on board ship designed for the very opposite purpose; and they cannot adjust themselves to every angle of incidence of eddies coming from above downwards.

A simple umbrella-shaped cap or better a truncated cone open

above overhanging the top of the chimney-pot is far more effective, though in the former an *ascending* eddy may impinge on its under surface and thence be reflected downwards.

But a nearly perfect cowl is Sugg's (Fig. 2), in which the mouth of the chimney-pot is closed by a horizontal plate with numerous perforations 1 inch in diameter, and the whole surmounted by a broad cap.

The ingress of eddies from above is thus effectually precluded, and when fixed over a ventilating shaft, the flue of a sun burner, a gas stove, or anywhere except over a coal fire, any reversal of the draught is prevented by a mica valve resting on an annular seat, but lifted by the least pressure from below, which is fitted in the cowl at a short distance beneath the perforated plate.

Appliances for Effecting Natural Ventilation

The simplest and most perfect is perflation, or the free passage of the wind through open doors and windows. Every room should have its air thus completely renewed at least once a day; the mere renewal is effected in a few minutes, but a longer time is required to dislodge the organic vapours, &c., from recesses behind furniture and the like. In schools and workshops this should be done during the intervals for meals; in churches, between services. Opposite windows greatly aid perflation, and it is highly desirable that in all such buildings the windows should be thus placed.

But in this climate it is not possible to have the windows and doors open to the extent required for perflation during the time a room is occupied, except in very warm weather, and recourse must be had to some special contrivances to maintain a constant renewal or movement of the air.

It is seldom, however, that the door of a bedroom might not be kept open (on a chain if preferred) at night, and this, with the open chimney, would generally suffice to keep the air fresh and wholesome; while for eight months in the year the windows might be open from two to twelve or more inches, with or without the intervention

of a blind to break the draught, if people had not a superstitious dread of night air, by far the purest in towns.

Of special contrivances the number is legion, but they may be arranged under the following heads according to the general principles of their action.

1. Direct communications with the outer air by means of inlets through the walls, and outlets in the same position or communicating with the chimney.

2. Ventilation by tubes for the admission of air, with or without similar tubes for outlets.

3. Appliances for utilising the heat evolved in the combustion of gas-lights for purposes of ventilation.

4. And those in which the heat of the stove is made available for warming the air entering by channels behind the fire, thus combining in one the heating and ventilating arrangements.

Sherringham's valve is an iron air brick or box fixed in the wall just below the ceiling, and communicating directly with the outer air, which, on entering, is directed upwards by a valve hinged below, and provided with side pieces so as to form a sort of trough or hopper. It can be regulated by a cord, and answers well whether as inlet or outlet, but is too unsightly for private houses. In barracks, dormitories, &c., it is one of the best ventilators, but for such large rooms several are required.

When these or any similar openings are arranged on the opposite sides of a room having two outer walls, the pressure of the wind and the warmth of the sun cause those on one side to act as inlets, and those on the opposite side as outlets.

To this class belong also the hollow beams open to the air at each end, perforated on the under surface, and divided in the middle by a transverse partition occasionally used in barracks, and the cornice ventilator of Messrs. Potts of Handsworth, consisting of a metal cornice carried round the room, divided longitudinally into two parallel channels, into the lower of which the fresh air enters by openings in the wall alternating with others on the under surface towards the room, so as to break the draught; while the hot foul air escapes by ornamental perforations in the upper one, and is carried off by several channels into a chimney or other exhausting shaft. When placed under favourable conditions it rarely fails to act efficiently.

Perforated ceilings with numerous air bricks between the ceiling and floor above, which must be well plugged or otherwise rendered air-tight, provide an excellent means of escape for the foul air in factories or rooms where there are many persons and lights. Special inlets should be provided in the walls above the heads of the occupants, or the cold draught from the doors and floors will be disagreeable.

Moore's louvred glass panes and similar window ventilators are too small to be of any use.

The next class is represented by the so-called Tobin's tubes, Dr. Chowne's system, &c.

Tobin's tubes are hollow, and may be ornamental, pilasters 6 to 8 feet high, standing against the walls of the room, open above, and communicating below with the outer air. They are fairly effective inlets, though less so than would appear at first sight, in consequence of the friction on the sides, and the angle which can rarely be avoided where they pass through the walls below. If their mouths are protected by gauze or perforated zinc to intercept the dust, this quickly becomes choked, and they cease to act at all. In any case special outlets must be provided in or near the ceiling.

Dr. Chowne's system may be defined as a combination of ordinary Tobin's tubes for the admission of fresh air with a similar set of tubes reversed, as it were, for outlets. These pass from the ceiling or cornice to an exhausting shaft above.

The third class comprises McKinnel's tubes and the usual surroundings of sun lights. In this connection we may describe an ingenious experiment. If a lamp be enclosed in a box, the only opening in which is a tube fixed in the upper side, there will be no movement or renewal of the air, and the light will soon burn dimly, and at length go out; but if this tube be divided into two by a vertical partition before the light is quite extinguished, it will presently become bright again, and the application of a smoking match will demonstrate an upcurrent in one section, and a down current in the other

division of the tube. The explanation is that in no closed space where there are lights or other sources of heat is the density of the air perfectly uniform, and the presence of two even adjacent openings leading to shafts of any length, together with the unstable equilibrium of the unequally heated and expanded air, sets up currents in opposite directions.

This is the principle of McKinnel's ventilating shaft consisting of two tubes, one within the other, the diameters of which are such that the circular area of the inner, and the annular area of the outer, are equal. The inner is, moreover, carried to a greater height than the outer which, above the roof, is exposed to the external air. The inner being more protected is always the warmer, and serves as an outlet, its action being aided by its greater height, and very much so if a gas light be fixed at its lower end, as in the sun lights in churches and public rooms. The shorter colder outer tube admits the fresh air. It acts best when all other means of entry or escape, as doors, &c., are securely closed. Of course it can only be applied to detached buildings, or to the upper stories of school houses, &c., some other means being employed in the lower. Open fires, unless self-ventilating, are incompatible with ventilation by McKinnel's tubes, for the strong suction of the chimney easily overpowers that of the inner tube, converting both tubes into inlets, and bringing down the products of combustion into the room. In churches and places where sun lights are used for lighting, heating and ventilation should be by warmed air. It is also found in practice that the heat of the inner tube is communicated to the outer, reducing or abolishing the difference of temperature on which the action wholly depends.

Most of the usual contrivances for carrying off the products of combustion of gas lights are quite useless, partly from their liability to reversal of the current by

the draught of the chimney, and partly from the friction produced in the tubes by numerous bends.

Mr. Simmance has, however, overcome all the difficulties incident to McKinnel's tubes and succeeded in making the gas-lights a powerful aid to ventilation. In his arrangement the outer tube, instead of communicating directly with the air, opens into and around the inner beneath the roof. Both act as outlets, the inner directly and the outer in virtue of the powerful secondary current produced by the passage of the hot air across the communicating apertures. As this action is independent of the temperature of the outer tube, the heat is retained in the inner by means of a lining of asbestos or slag felt, which, besides being the best of non-conductors is absolutely uninflammable even if incandescent. The high temperature is further maintained, and the entrance of downward eddies prevented by a Sugg's cowl, in which the possibility of the current being reversed and the products of combustion brought back, when the gas is burning low, through any stronger exhaustion exerted by a stove chimney, is precluded by the insertion in the flue, a short distance below the cowl, of a horizontal plate or diaphragm of mica hung by a central thread and closely seated on a rim. It is lifted by the slightest upward pressure but resists the strongest in a downward direction.

The gas burners are Sugg's perpendicular jets, a number of which are grouped beneath the mouth of the inner tube. The rays emitted downwards at an angle of 45°, that found experimentally to have the greatest illuminating power, fall on the walls and outer zone of the floor, while those passing upwards are thrown down by an enamelled iron reflector on to the middle of the floor.

The supply of fresh air must be provided by other means and may be warmed by hot water or steam coils, when, as in churches and public buildings, that system of heating is employed, or in private houses by Galton's stoves. It has been found that by Simmance's system the air of a crowded hall may be completely renewed several times in the hour, with no unpleasant draught, at least if the incoming air be warmed.

In the lower rooms of a building it will mostly be necessary to carry the pipes horizontally between the joists of the floor above until some wall is reached, but the temperature of the inner tube is such that little loss of velocity is involved.

The system is equally applicable to private houses if people could be induced to abandon hanging gasaliers and fittings, with their dangers of fire, leakage, deterioration of the air, blackening

of ceilings and insufferable heat, for one which combines the convenience of gas, with most of the advantages of electricity and is at the same time an efficient means of ventilation.

The last divison comprises a number of arrangements, which, however complex, are technically regarded as natural methods of ventilation, since no purely mechanical contrivances are introduced to effect the requisite movements of the air, which are brought about solely by taking advantage of the unequal densities of air at different temperatures.

The principle which underlies them all is that the incoming air is previously warmed without deterioration or change of composition, and that it consequently diffuses itself uniformly throughout the apartment instead of sinking towards the floor as cold and heavy air does. Again, the movements of air are less felt the warmer it is, so long as the temperature does not exceed that of the body; consequently in these systems air can be admitted in larger volume and be far more frequently renewed without giving rise to unpleasant sensations. A wider scope is permitted in the distribution of the inlets, and those which usually produce disagreeable and dangerous draughts, *i.e.*, the chinks around doors and windows, may be hermetically sealed without the purity of the air being reduced or the chimneys smoking.

The saving in fuel is enormous, since less need is felt for radiant heat, whether, as with the late Sir Douglas Galton's stoves, each room is warmed separately, and the heat usually wasted on the walls and chimneys is economised, or whether the warm air is supplied to the entire building from one central source, fires in the several apartments being thus rendered superfluous.

The primary aim in all these being that of warming the building, and ventilation comparatively secondary and subservient, we shall defer any further description until we come to the consideration of the various means employed for heating.

Artificial or Mechanical Ventilation

Artificial ventilation, in which the movement of the air is effected by mechanical means independent and irrespective of its temperature, is attained by the propulsion of fresh air into a room or the extraction of foul air from it, the escape of the foul air in the first case and the entrance of fresh air in the second being either specially arranged or left to chance.

Artificial ventilation or the employment of mechanical means, whether for the propulsion or extraction of air, is in every way inferior to natural ventilation, and should be resorted to only when under special conditions natural means are impracticable, as in the lower decks of ships, tunnels, and long galleries of mines; or insufficient, as for lifting and carrying away heavy dust, fumes and vapours. For such purposes mechanical extraction is indispensable; but the ventilation of buildings by propulsion, or the so-called plenum system, is a failure, for the pumping in of air is subversive of its diffusion and general renewal, creating intolerable draughts, while, however great its volume, stagnant spaces are left of foul unchanged air.

The extraction of foul air by fans is especially useful in factories and workshops where much dust is produced, as cotton and other mills, or where the air is charged with metallic fumes, filings or other injurious particles, in mines for the removal of noxious vapours and dust; in paper works, malt houses, laundries, &c., and for the ventilation of ships. Some, as Blackman's and the "Kosmos," are in the form of Archimedean screws from two to six feet in diameter, any number of which may be fixed in the walls, ceiling, or floor; others, as the "Aerophor" of Treutler and Schwartz of Berlin, of lesser diameter but of greater depth, revolve horizontally within cylinders communicating with the outer air.

The ventilation of ships of war and merchant vessels, in which other considerations as those of strength, speed, stability, carrying power, &c., must ever be paramount, has hitherto presented insuperable difficulties. But a system originally introduced by Messrs. Green and Sterkman seems to promise highly satisfactory results. Air is compressed by a machine, which in steam vessels may be worked by the engines, and conveyed by ordinary iron gas pipes to the several decks or compartments, where it issues from nozzles with a pressure of 3 to 5 lbs. per square inch. These nozzles, opening in special tubes or orifices, induce secondary currents from the external air twenty or thirty times

greater in volume than the delivery from the nozzles themselves. A second series may be arranged in inverse positions so as to act as exhausters of foul air, simultaneously if in separate channels, or alternately if in the same openings when two sets of these cannot be arranged.

During the construction of Mount Cenis and St. Gothard tunnels, the compressed air after having been used for working the boring machines was allowed to escape into and expand in the tunnels for the purpose of ventilation.

Gases, vapours, and light dust are best extracted from above ; metallic dust and heavy particles from below, or, if valuable, as that of gold leaf, received in water beneath a grated floor.

LAWS OF THE EXPANSION OF AIR

Before quitting the subject of ventilation we may, at the risk of repetition, give a few facts and formulæ bearing thereon.

BOYLE'S

~~Marriotte's~~ Law

" The volume of gases is inversely as the pressure," or

$$V : V^1 :: P^1 : P \therefore V^1 = \frac{VP}{P^1}$$

or when considering the question of density we may substitute barometric height for pressure, thus—

$$\frac{D}{D^1} = \frac{V^1}{V} = \frac{P}{P^1} = \frac{H}{H^1}$$

thus if H = 760 mm. (30 in.) or standard pressure

$$D^1 \text{ at } H^1 = D \times \frac{H}{760}$$

This law is not absolutely true, for the compressibility of air increases with the pressure. Non-saturated vapours obey this law, but saturated vapours are incompressible, a portion being liquefied with any increase of pressure, and the tension of that which is left in the state of vapour

remaining constant. Different gases, too, present slight deviations.

The density varies directly as the pressure and inversely as the temperature, expanding or contracting for each degree C. $\frac{1}{273}$ of its volume at zero. Instead of $\frac{1}{273}$ it is often more convenient in calculations to use $\frac{11}{3000}$.

If degrees F. be used the coefficient is $\frac{1}{493}$ of its volume at zero, *i.e.*, 32° F., or what is rarely used, $\frac{1}{461}$ of that at 0° F.

Thus the volume at any given pressure

$$= \frac{760}{\text{pressure}}, \text{ or } \frac{760}{\text{height of bar}} \times \text{its volume at 760 mm.}$$

and at any given temperature

$$\text{if } t \text{ be in C.}^\circ = \frac{273 \pm t}{273} \times \text{the volume at } 0^\circ \text{ C.}$$

$$\text{or if } t \text{ be in F.}^\circ = \frac{493 \pm t}{493} \times \text{the volume } 32^\circ \text{ F.}$$

A cubic foot of air at standard temperature and pressure weighs 566·85 grains. One litre of hydrogen at standard temperature and pressure weighs ·08936 grams, and other gases ·08936 × their atomic weight. In the case of compound gases this product must be divided by two.

Galton's Formulæ for the Dilatation of Air

Let M = its volume at standard temperature and pressure, *i.e.*, 0° C., and 760 mm. or 30 inches.

M^1 = its volume at t degrees.

a = coefficient of expansion of air by heat.

= ·002036, (= ·002) for 1° F., or ·003665 for 1° C.

Then $M^1 = M(1 + at)$ for temperatures above zero, and $= M(1 - at)$ for those below.

The velocity of wind in this climate is seldom less than 5—15 miles per hour, and may rise to 30—50. Greater velocities are rarely met with on land. In ventilation the velocity of the entering or outgoing air if cold should not exceed 1 or 2 feet per second. In main shafts it should not exceed 6 or 8 feet, and in secondary channels 3 to 4 feet per second. Extraction shafts should be vertical and circular; if part be horizontal the length of the vertical portion must be at least doubled.

Since the temperature of rooms is most agreeable when between 60° and 65° F., it is desirable that the incoming air should be warmed to 70° to 75° F., but never above 80°. Warmed air should be moistened by passing over water in the inlet tubes. All channels should be easily cleaned, and as short as possible. Dust may be intercepted by screens, care being taken not to offer too great impediment to the current. Draughts are to be prevented by breaking or deflecting the air-current.

Summary of Chapter VIII.

Ventilation or renewal of the air is said to be *natural* when the movement is the result of disturbed equilibrium between adjacent volumes, whether produced by meteorological changes or by the artificial warming or cooling of the air in parts; and *mechanical*, when, with or without the aid of temperature, it is effected by fans, pistons, &c.

The data are at **standard temperature and pressure** (799 mm. and 0°C), a cubic foot of *dry* air weighs 566·85 grams. Its coefficient of expansion is 0·00203 for each degree F., or 0·00367 for each degree C., and since air is a *mixture* of 4 vols. N and 1 vol. O, its s.g. $= \frac{4 \times 14 + 16}{5} = 14{\cdot}4$, while aqueous vapour being a gaseous *compound* of 2 vols. H, and 1 vol. O, its s.g. $= \frac{2 + 16}{2} = 9$. **Water vapour is, therefore, lighter**

than air, and moist air than dry, as warm is lighter than cold, and the amount of aqueous vapour that air can hold increases with its temperature.

The equation for velocity of movement of air due to difference of temperature based on that of falling bodies is $v = 8\ \sqrt{Ha\ (t - t'}$, in which $v =$ velocity of ascending air in feet per second, $H =$ height of shaft in feet, $a =$ coefficient of expansion, and t, t' the temperatures of the air in the shaft and outside respectively, [8 being $\sqrt{\ 2\ g}$], but allowance must be made for friction.

De Chaumont's formula which, according to the factors known, will give either the (D) delivery in cubic feet per hour, or the (Φ) area of the combined inlets and outlets, ($\Phi = I + O$)

$$(1)\ D = I \times 200\ (\sqrt{h\ (t - t') \times \cdot 002})$$
$$(2)\ \Phi = 100\ (\sqrt{h\ (t - t') \times \cdot 002}),$$

or the area of the inlet may be multiplied by the reading oı an anemometer.

The air of a room cannot be renewed more than three times per hour in cold or four times in warm weather without causing perceptible draughts.

In houses **natural ventilation is often neutralised** or reversed by the relative positions of stairs, chimneys, &c.; and cold, friction or insufficient supply of air are the causes of smoking chimneys. **Cowls** have no propulsive or exhaustive power, their function being that of excluding down draughts.

Inlets and outlets may be at distances from one another, or take the form of concentric tubes, the naturally higher temperature of the inner, or of any tube intended for an outlet being greatly assisted by a gas burner. Gaslights as "sunlights" may be made subservient to ventilation instead of deteriorating the air. **The perfection of natural ventilation** for domestic purposes is presented by Galton's stoves, which supply warmed fresh air equal to that drawn out by the chimney with an ordinary fire, being 3 to 6 or even 8 cubic feet per second.

All **systems of ventilation by warmed air**, or of extracting foul air by heated shafts are strictly *natural* in the sense of being based on the spontaneous movements of volumes of air at different temperatures. In mechanical ventilation revolving fans or archimedean screws are used, or air is compressed and then allowed to expand: impulsion being however very inferior to exhaustion as regards diffusion. The *density* of air (a gas) varies directly as the pressure and inversely as the temperature, and

conversely for the expansion. The coefficient being $\frac{1}{273}$ or $\frac{11}{3000}$ of its volume at zero for each degree C., and $\frac{1}{493}$ or $\frac{1}{500}$ of its volume at the same 32°F. for each degree F.

Galton's formula for dilatation. M being volume at standard pressure and temperature, M' that at t degrees, and a the coefficients $M' = M(1 + at)$ for temperatures above zero (or freezing), and $M' = M(1 - at)$ for those below.

QUESTIONS ON CHAPTER VIII.

1. How can the external air be admitted into a room without causing draughts (a) through the windows, and (b) through holes in the walls? 1885,E.

2. What is meant by "natural" and "artificial" ventilation? To which class do systems based on the circulation of warmed air, but without mechanical means, as fans, belong?

3. What is meant by ventilation by propulsion? Describe one method of carrying it out. 1885,A.

4. How are the movements of the air in rooms produced? How large an inlet opening is required for each person, and why? 1887,E.

5. What are the forces that produce natural ventilation? How may the action of the wind be utilised in practice? 1888,E.

6. What are the best means of ventilating a room without draughts? If possible, illustrate your answer by a sketch. 1894,E.

7. Explain the law of Montgolfier, and apply it to the following case:—Height of room from floor to ceiling, 12 feet; distance from the throat to top of chimney, 20 feet; temperature of room, 68° F.; of outer air, 46° F.; sectional area of chimney throat, 1 square foot; superficial area of floor space, 834 square feet. Further, if five men occupy the room for four hours, what amount of CO_2 per 1,000 cubic feet of air will be present in the air of the room at the end of that time? 1896,H.

8. Describe a system of ventilating an ordinary sitting-room, and explain how the change of air is effected. A room of 1,000 cubic feet is occupied by one person: how often should the air be changed each hour? 1899,E.

9. Describe the arrangement of Tobin's tubes, McKinnel's tubes, and Jebb's system of ventilating prison cells? Under what conditions may McKinnel's tubes fail of their purpose?

10. Why do chimneys serve as exhaust shafts in ventilating rooms (*a*) when a fire is burning, and (*b*) when there is none? How and under what circumstances may the wind (*a*) aid the upcast draught, or (*b*) cause a down draught in the chimney?

11. Describe the general course of air currents in a house of several storeys. Does a window in a water-closet on a landing on a floor other than the topmost act as an inlet or an outlet?

12. Discuss and compare the merits of ventilation by mechanical means on the principles of propulsion and of exhaustion. Describe Blackman's fans and any similar apparatus.

13. Describe Galton's stoves and the Canadian jacketed stove.

14. Describe the ventilation of the Houses of Parliament.

15. Describe the German system of central heating and ventilation combined, with the arrangement of coils or Heitzkörper.

16. Discuss the possible application of the expansion of compressed air to the cooling of buildings in hot weather or climates.

17. Describe the usual course of the air currents in a room with an ordinary open fire-grate, and ill-fitting floor-boards, doors, and windows. What would be the consequence of hermetically closing these crevices against draughts?

18. How may gas burners be made to subserve ventilation?

CHAPTER IX

Laws of Heat

Heat is propagated in one or more of three different modes according to the nature of the medium surrounding the source. These modes are radiation, conduction, and convection. In a perfect vacuum radiation alone is possible, and within a solid body conduction only, but all three may, and generally do, co-exist when the medium is gaseous, and conduction and convection occur together in the case of liquids.

Radiation.—Every heated body gives out heat in all directions, producing undulations in the ether, like those of light, and governed by the same laws, thus :—

1. Radiation takes place in vacuo, as well as in air, without warming the intervening space.

2. Radiant heat is propagated in all directions with equal intensity.

3. And in right lines ; it may thus be intercepted by interposing a screen.

4. It is also subject to the laws of refraction in passing from one medium to another of different density, but this property has no practical bearing on the subject under consideration.

5. The intensity of radiant heat passing from one body to another depends on the intensity of its source, and on the distance it traverses, and like that of light is directly proportional to the temperature of the source, and inversely as the square of the distance.

6. Radiant heat, falling on a solid body, is reflected in the same manner as light, *i.e.*, the angle of reflection is equal to the angle of incidence, and real foci are formed by reflection from concave surfaces, though the virtual foci of optics have no analogues here.

7. At the same time a portion of the heat is absorbed, the proportions reflected and absorbed being inversely as one another, and depending on the material, surface, and colour of the body in which the rays impinge.

8. Radiation and absorption, on the other hand, are equal and affected by the same conditions.

9. As different bodies are said to be transparent or opaque as regards light, so they are diathermanous or athermanous as regards heat.

Transparency and diathermancy may go together, as in the case of clear glass, but a body may be opaque and yet diathermanous, or transparent and athermanous to obscure rays, or the same body, as glass, may permit the passage of the sun's heat

with facility, that of a fire imperfectly, and that from a dark though hot body, as a metallic cylinder of hot water, scarcely at all. And again, the heat which has passed through a glass plate is stopped by one of alum, just as a blue glass is transparent to blue rays, but opaque to the red and yellow.

Practical Illustrations and Applications of the Laws of Heat

It does not raise the temperature of the space through which it passes. (This is absolutely true only of a perfect vacuum, for air is matter, and capable of being warmed by conduction, though slowly.) Thus, on the summit of lofty mountains, or in balloon ascents, persons may find their faces scorched by the sun's rays, while the air, of extreme rarity, *i.e.*, not far removed from a vacuum, is intensely cold, and one may roast an ox in the open air, though behind a screen a thermometer would not indicate any rise of temperature.

A black wall absorbs and radiates much heat, a whitened one reflects most and absorbs and radiates little. Snow reflects very perfectly, but absorbs heat very slowly. Polished metallic surfaces reflecting much of the heat that falls on, or is conducted to them, are slower in becoming hot than dull ones. Steam pipes and engine fittings therefore are kept bright, but boilers and cooking utensils act best when black and rough outside.

The glass of greenhouses allows the sun's rays to enter, but since these, when radiated from the walls, &c., have been converted into obscure rays to which glass is comparatively athermanous, they as well as those radiated from the heating apparatus escape with difficulty. Glass thus imprisons the heat that is received from the sun or emitted within the greenhouse, while a glass screen protects from the heat of a fire. The heat given out by an open fire is mainly radiant, warming persons and furniture, and the walls more than the air of the room.

The art of heating by open fires to the best advantage consists in so constructing them that the largest possible amount of heat shall be radiated, and the least lost by being absorbed in the brickwork behind.

Every body in the act of combustion gives off a certain amount of heat which is constant for like chemical composition. It is estimated as so many units of heat, a unit being the quantity required to raise one pound or 1 kilogram of water one degree F. or C. respectively.

We may here notice the difference between intensity and quantity of heat. There is more heat in a copper of water at 50°C. than in a cupful at 100° C., but the intensity of the latter, the temperature as it is called, is greater. The intensity of the heat of an electric light is the greatest known, but its quantity so small that it has little or no effect on the air of the room.

Heat and Products of Combustion

The heat given off by the combustion of the principal fuels is as follows in pound and F.° units :—

Wood (with 20 per cent. of water) .	5040	Units of heat for each pound of fuel to 1° F.
,, perfectly dry . . .	6480	
Peat dried naturally . . .	7150	
,, ,, artificially . . .	8736	
Coke	10970	
Charcoal	12000	
Coal (mean of many kinds) . .	13007	
Petroleum	20240	

Carbon burnt to carbon monoxide (CO).	4464
,, ,, carbon dioxide (CO_2).	12906–14040
Hydrogen burnt to water . .	62535.

It will be seen that the heating power of coal is about twice as great as that of wood, while petroleum possesses weight for weight half again as much heating power as coal.

When carbon is completely burned or oxidized into carbon dioxide, 12 parts by weight of carbon unite with 32 of oxygen $C + O^2 = CO_2$, but when the supply of oxygen is insufficient, a further part of the carbon becoming incandescent in an atmosphere highly charged with and practically consisting of carbon dioxide, combines with it to form carbon monoxide, $C + CO_2 = 2CO$. This is given off from charcoal fires and closed "slow combustion" stoves, and is incomparably more poisonous than the dioxide which also evolves six times as much heat in the act of formation.

If, as in a large clear open fire, the heat be more intense, this CO, on coming in contact with the air beyond, burns with a blue flickering flame, and is reconverted into carbonic acid $2(CO) + O_2 = 2(CO_2)$.

Another product of imperfect combustion, which is also highly poisonous to vegetable as well as animal life, is acetylene C_2H_2. The sulphur present in coal, as iron pyrites, &c., is burnt into SO_2, and appears in gas as H_2S and CS_2. The former is in great part removed in the purification by means of oxide of iron, but no satisfactory process has yet been found for removing the carbonic sulphide to the same extent.

Sulphurous and Sulphuric Acids.—These are always present in the atmosphere of towns where coal is burnt, and may often be seen upon windows in the form of ammonium sulphate. *Coal* contains from about 0·75 to 4 per cent. of sulphur, the quantity present in common coal being on an average 1·5 per cent. *Coke* contains from 0·6 to 2 per cent. of sulphur, the average quantity being 1·25 per cent. *Coal gas* contains from 12 to 40 grains of sulphur per 100 cubic feet, the average being 20 grains. In certain localities where sulphur is burnt or metals refined there is often at times a large escape of sulphurous acid into the air. The rain which falls on the roof of the London Hospital College contains from 0·942 grain to 4·357 grains of sulphuric acid (H_2SO_4) per gallon. This is equivalent to from 13·46 to 62·24 parts per million.

To calculate the quantity of air required for the combustion of any given fuel, we may use the formula, $12C + 36\left(H - \frac{O}{8}\right)$, which gives the *weight* of air chemically necessary for the combustion of a unit of weight of a fuel, the composition of which is known; and if the unit employed be one pound, we may obtain the volume in cubic feet of air at 62° F. required, by multiplying the weight by 12·844, though in practice it is found that from half again to twice as much air as is shown by this formula to be theoretically or chemically necessary must be supplied.

Thus a pound of coal requires 300 cubic feet of air, and one of dry wood 160.

Propagation of Heat

The heat emitted by an open fire, being chiefly radiant, does not sensibly raise the temperature of the air, but warms the walls, &c., by which it is converted into the dark rays, which are then propagated by conduction. Hot water pipes and closed stoves at low temperatures on the other hand warm the air itself by convection, the walls and furniture long remaining cold, but if strongly heated, as Perkin's hot-water pipes under high pressure, they give out also much radiant heat, the more the higher their temperature, or more correctly, the greater the

difference between their temperature and that of the surrounding air.

For transmitting heat from any source to the surrounding medium copper is more than four times as efficient as iron, and but for the higher prime cost would be the best material for closed stoves, hot air, water, or steam pipes, &c.

Conduction of heat takes place through all solids, and to a certain extent through liquids and gases, but these are very bad conductors, and the propagation of heat through them is usually effected by means of convection.

Metals are better conductors than stone, &c., and these than wood or vegetable fibres; while woollen and silk fabrics are worse still.

Good conductors give off their heat rapidly to the surrounding air, or to bodies in contact with them; and, if colder, they withdraw heat from other bodies in like manner. Thus the best conductor feels hottest if it be hotter than the body, and coldest if it be colder. For example the fender, stone hearth, boards, and woollen carpet of a room without a fire will, of course, be of the same temperature, but the first will appear the coldest, and the last the warmest to the bare hand or foot; if, on the other hand, they be all at a temperature above that of the body the sensations will be reversed. So, a housemaid interposes a piece of carpet when kneeling on cold stones, and an engineer might do the same when kneeling on a boiler, in either case the carpet will soon assume the temperature of the surface on which it lies, but it imparts heat to or withdraws it from the person more slowly.

So, too, woollen clothing retains the heat of the human body, non-conducting jackets that of boilers, and so on, and blankets are used to keep out the external heat in packing ice. The handles of kettles, made of wood, porcelain, or bone, and many other contrivances, are illustrations of the use of bad conductors. That water is a bad conductor is seen by the slowness with which a boiler can be heated from above or even from one end when convection cannot come into full play, but it is a better conductor than air, as one finds on getting into a bath a little above or below the temperature of the air.

Porous or felty materials, themselves bad conductors, and containing air in their interstices, are very useful where one wishes to impede the escape and loss of heat; thus a boiler may be enveloped in felt to retain the heat while the hot water pipes are of blackened metal, to aid the emission of heat by conduction and radiation.

Convection depends on the property of mobility characteristic

of fluids, which permits those portions which having been heated expand and become lighter to rise, their place being at once taken by the colder and heavier parts. A circulation of the air or water is thus kept up, and the whole mass, although conducting heat but very imperfectly, soon becomes warmed. This takes place alike in the kettle, the room, or the open air, where similar movements are the main cause of winds. But since the currents set up take the lines of least resistance, the position of the source of heat is of great importance. Theoretically this would be best beneath the space to be warmed, as when a kettle is placed on a fire, or the fire is lighted beneath a copper or boiler. Thus, too, hot pipes are laid beneath the floor in churches, and the Roman baths were warmed by hot air flues in the brick work of the pavement.

In rooms a closed stove should be as near the middle as is convenient, and an open one in the longer, not, as is so often seen, the shorter, side.

But on the construction of the grate itself depends whether about one-eighth or three-fourths of the heat to be obtained from the combustion of the fuel is used or is wasted.

Heating by Open Fires

If the whole of the heat generated in the combustion of coal could be utilised, one lb. would be amply sufficient to warm a room twenty feet square by twelve feet high to a temperature 10° F. above that of the outer air, *i.e.*, making no allowance for loss by ventilation and conduction of the heat through the walls.

If the air be renewed two or three times in the course of an hour, two to three lbs. of coal per hour, or twenty-four to thirty-six lbs. for a day of twelve hours, will be necessary; and in fact little more, say four lbs. per hour, is actually required in German stoves standing out in the body of the room, where the only direct loss is by the chimney, and even much of this is returned to the air of the room in the course of the iron flue towards the outer wall.

But our English open grates fixed in the wall immediately beneath a brick chimney certainly do not consume less than eight lbs. of coal per hour. Allowing 300 cubic feet of air for the combustion of one lb. of coal, this gives 2400 cubic feet hourly, but at the lowest computation four to six cubic feet of air pass up a chimney per second, amounting to 14,000 to 20,000 per hour; and in chimneys as frequently constructed, the air

passes out at the rate of ten to fifteen feet per second, or 35,000 to 40,000 per hour.

In such a room containing 4800 cubic feet of space, the air would be renewed four, six, or eight times in the hour, according to the strength of the fire. If the incoming air were warm such ample ventilation would he highly beneficial, but as it is, the cold air drawn in at every aperture, whether intended for ventilation or not, produces unpleasant and cutting draughts. What with the loss of heat up the chimney, its conduction into the brickwork behind the grate, and the warming of the cold incoming air, General Morin has calculated that $\frac{7}{8}$ths of the heat generated is actually lost or wasted. The large volume of cold air is, however, by no means uniformly warmed, and parts of the room remain cold, while near the fire the radiant heat may be well nigh insupportable.

The path followed by the currents is something like this ; the cold air, much of which enters beneath the door, is drawn along the floor, as the feet of the inmates can testify, until it becomes warmed by contact with objects near the fire, when part is carried straight up the chimney and lost, and part rises towards the ceiling whence after a time it descends along the opposite walls to rejoin the general circulation.

An American architect, Mr. Briggs, from a number of experiments in which the incoming air was rendered visible by being charged with smoke, came to conclusions somewhat different from those commonly accepted. The draught in the inlets was maintained by a strong heat, and the outlets were twice as large as the inlets. With the inlet at the floor and the outlet at the ceiling on the opposite side, the stream of air entirely failed to reach the breathing line of the occupants of the room. Step by step he raised the inlet and lowered the outlet, but no improvement appeared till the two apertures took the positions shown in Fig. 7. Still, however, the diffusion of the pure air was but partial, and it was only when a high inlet and a low outlet were placed one above the other on the *same* side, that the diffusion was uniform throughout the room. This is the relative position in Galton's stoves.

Still the open fire is no less imperfect as a means of ventilation, than wasteful as a source of heat, for it leaves the hot stratum of foul air near the ceiling undisturbed, while carrying off much of the fresh air as fast as it enters the room.

Cardinal Polignac, in a work which he published in 1713, under the assumed name of Gauger, first expounded the principles on which an open fire may be so constructed as to economise fuel and ventilate a room with warm air, thus obviating draughts,

or chink-winds as they have been well called. His book was translated into English in 1716 by Dr. Desaguliers, who adapted the grate for burning coals instead of wood. Benjamin Franklin, Count Rumford, Dr. Julius Jeffreys, and Sir Francis Galton have all followed on the lines laid down by the Cardinal, to whom the real merit of the invention belongs. The essential features of Polignac's stove were parabolic jambs, by which the greatest possible quantity of heat was radiated and reflected into the room, a chambered space, or, as he called it, a series of caliducts behind the back and jambs, communicating on the one hand with the outer air, and on the other with that of the room above the mantel, a solid bottom to the grate to ensure slow combustion, but with an aperture or *soufflet*, *i.e.* a blow-hole, to be kept open till the fuel was well kindled, and a four-way valve by which the air could be shut off from the caliducts or from the room, and the quantity and temperature of that admitted to the apartment adjusted at pleasure.

All open stoves should be so constructed as to burn the fuel completely but slowly, that the draught up the chimney shall not be in excess of the requirements of ventilation, which consist in maintaining what we have termed a permissible degree only of impurity, *i.e.*, keeping the added or respiratory CO_2 at or under ·2 per 1000 parts. They should have, if not parabolic, at any rate slanting jambs, that the heat may be thrown forward and the largest possible radiating surface secured. For this purpose they should also be wide and shallow from front to back, and stand well forward into the room.

Complete combustion is aided by making the back and cheeks of fire-brick, which being a bad conductor retains the heat in contact with the coals, whereas iron withdraws it from the fuel and conducts it into the wall.

Slow combustion is secured by having the bottom solid or with only a small opening which may be closed when the fuel is fully ignited, and by having the throat of the chimney as small and as far back as is compatible with the passage of the products of combustion ; while lastly, the shaft of the chimney should be as small, smooth, and straight as possible to minimise the friction and escape of warm air. For this purpose glazed stoneware drain-pipes are far better than rectangular brick flues. They do not afford a lodging for soot, and when swept are as clean as when first put up.

Smoke and soot are evidences of imperfect combustion, that is of waste, of so much fuel thrown away, or worse, to the loss of the consumer and the injury of the public health. By some means or other all fires, and not those of factories only, should

be made to consume their own smoke or not to produce smoke at all.

The forms and patterns of slow combustion stoves are innumerable, from the simple "country parson" to the fanciful "Nautilus," but they all aim at fulfilling the conditions above stated, and do so more or less perfectly. Most of them can be fitted to existing chimneys without any considerable alteration in the masonry, but they do not in themselves provide for the warming of the incoming air.

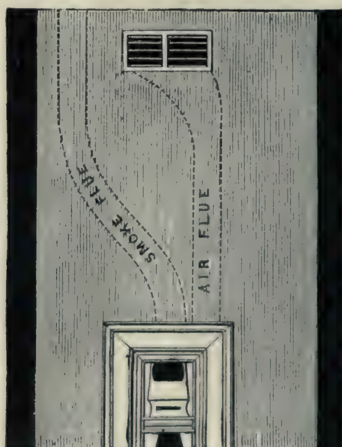


FIG. 3.

This may be effected by means of hot-water coils in each room through which the fresh air is admitted, or by a central heating apparatus in the basement, serving for the whole house; but perhaps the simplest and best is the stove which bears the name of Sir Douglas Galton, in which the waste heat which would otherwise pass up the chimney is utilised to warm the incoming air in each room, the windows, doors, and floors of which may be made absolutely air-tight without detriment to the ventilation.

"Fresh air is admitted to a chamber formed at the back of

the grate, where it is moderately warmed by a large heating surface, and then carried by a flue adjacent to the chimney to the upper part of the room, where it flows into the currents

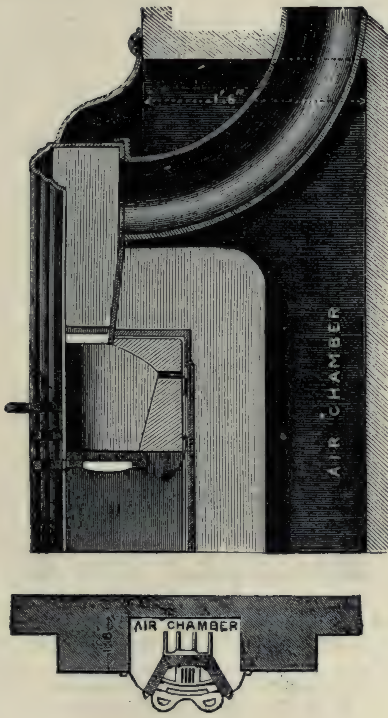


FIG. 4.

which already exist there (Fig. 3). The body of the stove is of the best cast-iron, and consists of three pieces connected by screws. The first piece forms the moulded projecting frame,

the second the body of the grate, and the third the nozzle or connection with the smoke flue, the bottom flange of which is bolted to the back of the grate."

"The fireplace has a lining of fire-lumps in five pieces—two sides, one back piece, and two bottom pieces. The object of this fire-clay is to prevent the contact of the incandescent fuel with the iron, and by preserving a high temperature in the vicinity of the fuel to assist the combustion. The bottom is partly solid, being made of two fire-lumps placed one on each side, and supporting an intermediate cast-iron fire-grating which occupies about one-third of the bottom of the grate." "A clear space

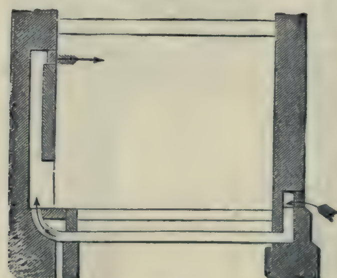


FIG. 5.

half an inch deep is left between the back piece of fire-lump and the iron back of the grate, through which a supply of air passes from the ashpit beneath, through a slit in the fire-lump and on to the upper part of the back of the fire." "The air thus brought into contact with the heated coal is already at a high temperature from having passed through the heated fire-lump, and is forced into contact with the gases from the coal by means of a piece of fire-lump which projects from the back of the grate" (Fig. 4).

Thus complete combustion is ensured of the fuel and of its gases, as well as of any little smoke that may be produced, the combustion is slow, and the heat which would be lost is utiiised for warming the air that enters the chamber at the back of the stove, from which it pours into the room in front of the chimney breast, a little below the ceiling, and circulates in a succession of curling streams for a long time ere it at length is drawn into the current passing out of the room by the chimney.

The means by which the cold air gains access to the heating chamber will depend on the general construction of the house. When the stove is placed in an outer wall the channels will be short and open directly behind. Where the wall is a party one, they must be carried laterally or beneath the floor to the nearest outer wall or to a space beneath in the basement, provided always that the air introduced be free from a suspicion of impurity (Fig. 5).

Before proceeding to consider heating by means of closed stoves, hot-water pipes, &c., we may observe that the prejudice in favour of open fires is not merely a sentimental one. The luminous and the obscure heat-rays differ in their action on the animal body, and the former, all associations apart, are more pleasurable and healthy. The invigorating sensations called forth by the warmth of a camp fire when the air around is cold and keen are enough to prove this. The question of the "dryness" of artificially heated air—which, while generally disagreeable, is, under certain circumstances, an advantage—is one of relative, not of absolute humidity.

Heating by Closed Stoves

This method is in this country almost confined to halls of houses, churches, and places of public assembly; but in Germany and Russia, where the winters are severe, it is much used in dwelling rooms.

It has the advantage of economy of fuel, very little of the heat being lost by the chimney and none through the walls; but the heat given off is not, unless the surface of the stove attain a very high temperature, of the radiant kind. In any case such stoves warm the air itself rather than objects in the room, and they exert very little ventilating action as compared with open ones.

It is commonly, though erroneously, supposed that closed stoves and indeed all contrivances for warming the air itself, dry or even burn it, and it is usual to supply additional moisture from pans of water on or beneath the stove. It is true that air so heated feels disagreeably dry, and with some persons causes a sensation of dryness or irritation in the throat and chest, which is obviated by the evaporation from the vessels of water above mentioned; but the explanation is that our sensations, pleasurable or the reverse, depend on the relative rather than on the actual amount of watery vapour present in the air. The quantity of water which the air is capable of holding in the state of invisible or impalpable vapour varies with the temperature. When the

air already contains as much as it can hold, it is said to be saturated; but since the quantity required to saturate the air at one temperature will be quite insufficient to do so at a higher, the air will feel drier when heated though the actual weight of water in each cubic foot remains the same. Whatever the temperature, the air feels most agreeable when it contains about three-fourths of the possible quantity, or as we say when its humidity is 70 to 80 per cent. of saturation, or 70° to 80° as it is sometimes called. In crowded assemblies so much vapour is given off from the lungs of the persons present that the air is saturated, and the excess is deposited on windows and walls. Such hot saturated air is most oppressive, and under these circumstances the drier the air supplied the better.

Stoves are often made of cast iron, and constructed to burn coke or anthracite; but a more objectionable plan could not be devised short of the charcoal brazier, with which the French warm their bedrooms and sometimes with accidentally or intentionally fatal effect. Coke and anthracite generate much carbon monoxide, and even if the joints could be kept tight in spite of the alternate expansion and contraction of the metal, cast-iron itself is, in a higher degree than other metals pervious to gases, so that as MM. St. Clair Deville and Troost have clearly shown, in a series of experiments conducted at the request of General Morin, the products of combustion can be detected in the air surrounding the best made cast-iron stoves; besides there is reason to believe that the dioxide is actually converted into monoxide by the action of the iron. The comparatively harmless sulphurous acid betrays itself by its smell, whereas the carbonic oxides are odourless, and therefore unrecognised or unsuspected.

Wrought-iron is less pervious and should be preferred; the joints, too, might be riveted and fitted as they are in boilers, and precautions taken further to ensure a good draught, or the stoves may be lined with fire-brick and covered with porcelain tiles, as in the better class of German houses.

There is a strong prejudice against gas stoves, though under like conditions the products of the combustion of gas are less irritating than those of coke or coal: so much so indeed, that chimneys are erroneously deemed unnecessary. Mixing the gas with a large proportion of air before it reaches the burner, first suggested by Bunsen, ensures complete combustion of the carbon into CO_2; but when the pressure of gas is too strong or the orifices are choked up some CO may be formed, soot deposited, and a product of the imperfect combustion of the hydrocarbons (C_2H_2 acetylene) given off. This, which is very poisonous, may be recognised by its peculiar smell, quite

distinct from that of raw coal gas, and more pungent though less offensive. It is likely to be formed along with soot, &c., when the flames of a gas stove are long, yellow, and luminous, instead of being short, blue, and emitting but little light. The flame of a laboratory Bunsen lamp, though intensely hot, is quite invisible in strong daylight.

With a view to impart to a gas stove the cheerful appearance of coal, and to obtain as much radiant or luminous heat-rays as possible, the flame of a series of ordinary jets or of Bunsens is made to heat to incandescence a mass of "fire-lump," rough pieces of clinker or of asbestos, or spun asbestos spread upon a screen.

The gas cooking stoves let on hire by the companies are nearly perfect in their action ; the rings of jets for boiling kettles and saucepans are independent of the capacious oven heated from within, which can be kept for any length of time at any desired temperature. For baking bread they are equal to the hot-water ovens now adopted in all large bread or biscuit factories, the temperature being maintainable for any number of hours without the necessity under which the common baker labours of over-heating the oven at starting.

Sir W. Siemens combined the advantages of gas and coal by substituting for the lumps of asbestos or fireclay in the gas stove pieces of coke. The fire can be lighted or extinguished at a moment's notice, or left without fear of its going out, while the burning coke evolves instead of merely radiating heat. The ashes, which are but small in quantity from the thoroughness of the combustion, are received in a pan beneath, and a fresh charge of coke superposed daily on what may be left from the previous day. A row of gas jets, from a perforated wrought iron pipe, may very conveniently be used instead of paper and wood for lighting and relighting ordinary coal fires, being turned off so soon as the fuel is kindled.

The asbestos in gas stoves does not increase the total amount of heat which is dependent on the process of combustion, but it transforms it into radiant or luminous heat, and enables the gas stove, like an open one, to warm persons and objects rather than the air. Oil, as will be seen by reference to the table on page 187, has a higher heating power than coal, and is sometimes used as fuel, as in Rippingille's portable cooking stoves. Its fluidity presents obstacles to its use except in special apparatus.

Ritchie and others have contrived elegant stoves for heating halls, &c., suited for burning gas or oil, and in which the products of combustion, instead of being carried off by a chimney, are intercepted and absorbed by water containing ammonia, &c.,

in solution. Sulphurous acid and carbon dioxide are completely removed, but this has not been shown of the CO, which can so far as we know, be stopped only by the chlorides of copper or palladium or by fresh blood.

The idea of using the same fire to warm the room and the fresh air admitted has also been applied to closed stoves, as George's calorigens, which burn coal, oil, or gas; Dr. Bond's thermohydric stove, an improvement on the calorigen, and others, in which the products of combustion are carried off by a flue with the least possible waste of heat, and pure air is admitted from

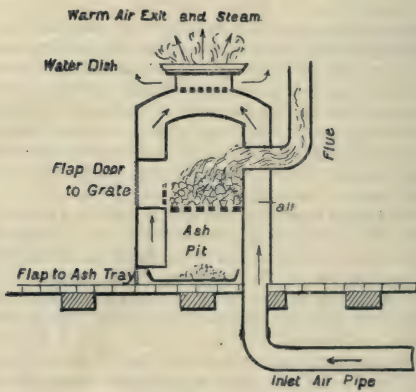


FIG. 6.

without, warmed, and, if thought necessary, made to take up water vapour in its passage through the stove.

An inexpensive device for combining the economy of heat presented by a closed stove with ventilation by means of warmed air is much used in Canadian schools, and might well be adopted in village schools in this country, mission halls, &c. The stove is enclosed in a jacket of iron considerably larger than itself, which forms a hot-air chamber from which the grate is shut off by a horizontal passage open to the room. Fresh air is admitted to this chamber by a pipe beneath the floor, and escapes when heated by a grating at the top (Fig. 6).

In places of public assembly and in buildings containing a large number of chambers occupied under similar conditions, but where separate fires are undesirable, hot water or steam pipes may be used. Either water or steam may be under low or high pressure, the advantages of high pressure being that not only is a higher temperature obtained, but that much of the heat passes off in the radiant form, rendering the apparatus more effective.

Under the ordinary atmospheric pressure of 14·7 lbs. to the square inch, water boils at 212° F., under four atmospheres at 291°, and under ten at 357°. These temperatures may be obtained under pressure without the generation of steam. Steam under high presure is the most efficient, but where there is not a resident engineer hot-water pipes are generally to be preferred.

In ordinary hot-water pipes the flow is brought about by the tendency of the heated and expanded water to rise, and of that which has been cooled by the giving off of its heat to sink. To render this flow as equable as possible, both outgoing and return pipes should be as straight as circumstances permit, and the heating apparatus should be at a lower level than the place to be warmed, for the velocity of the flow is the greater the higher the vertical column. When this is not great the average temperature of the water in the pipes will be lower, but in no case, when the movement of the water is dependent solely on the difference of temperature in the flow and return pipes can a mean temperature of more than 160° to 180° F. be counted on. When the pipes have to traverse long distances the movement may be aided by the introduction into the return pipe of an Archimedean screw kept constantly at work.

The usual form of hot-water apparatus with high pressure is that of Perkins, which consists of a continuous or endless iron pipe closed in all parts and coiled for one-sixth of its length in the furnace. It is completely filled with water, the expansion of which is provided for by a cylinder called an expansion tube fixed at the highest point. The pipes are filled by a small pipe attached just below the expansion tube. The air is expelled by repeatedly forcing water through the pipes, but care is taken that the water shall not rise into the expansion tube. The filling tube and the expansion tube are then securely closed by screw caps. When the water expands by heat it rises in the expansion tube, compressing the air enclosed therein, the bursting of the apparatus being guarded against by a safety valve or plate.

A temperature of 300° F. can be maintained in the tubes under this system.

Heating by steam is especially applicable in factories where

the exhaust steam of an engine can be thus turned to account, and by steam under high pressure direct from the boiler when great distances have to be traversed. Mr. A. B. Reck, of Copenhagen, has devised an ingenious system of combined heating, ventilating, and electric lighting. The pipes are coiled, not in a furnace, as in Perkins' system, but within a high-pressure boiler, the waste steam of which is utilised for working a series of dynamos, thus providing electric light without any further cost than the original apparatus. When it is not required for heating the pipes can be disconnected and the dynamos worked alone. There are also arrangements calculated to effectually prevent the pipes from bursting during severe frost.

A most interesting application of superheated steam has been carried out at Lockport, in America, where the houses are supplied from a central source through three miles of pipes, and a pressure of 35 lbs. to the square inch is maintained at an expenditure of four tons of anthracite in twenty-four hours. The mains are covered by non-conducting material and fitted with expansion tubes of a peculiar construction at every 100 feet. Each house and room supplied is provided with a valve for cutting off the steam when desired, and it is used for warming, cooking, and as a motive power. By turning a jet of superheated steam into cold water a pailful can be raised to the boiling-point in three minutes. The whole cost of fittings is from £30 to £100 per house according to its size and the variety of purposes to which the steam is put.

Ventilation by Warm Air, or Heating and Ventilation Combined

This has been already referred to in one or other of its simpler forms as applied to single rooms; but we shall now consider its application to large buildings as a whole, whether these consist, like churches, houses of parliament, and theatres, of but a few large chambers, or, like prisons, &c., of numerous small apartments.

Typical or representative forms of this method may be seen in Sir J. Jebb's system of ventilating prisons, in the English Houses of Parliament and the French Chambers, the great opera-house at Vienna, and the private houses of Drs. Hayward and Drysdale at Liverpool, or Dr. Hogg at Bedford Park. Sir J. Jebb's system of ventilating prison cells is the same as that originally proposed by Dr. Sylvester and General Morin, and consists in the extraction of the air at the lower part of the cell, and its

admission near the ceiling, thus maintaining a uniform temperature. The fresh air entering the basement is warmed in long chambers heated by hot-water pipes. It ascends to each cell by separate flues, built in the inner walls adjoining the corridors and opening just below the ceiling, while the foul air leaves the cells at the floor level to ascend by flues in the outer walls to the roof, where it is carried to a shaft in the ridge of the roof by the aid of the current of hot air from the chimneys of the furnaces, which terminate in the loft beneath the roof, instead of as usual passing through it. In the cellars of the Bank of England jets of gas are kept burning in the upcast flues.

All systems admitting fresh air near the ceiling and extracting the foul near the floor are radically wrong. For the pure air at once mixes with the products of respiration and combustion, which rising in consequence of their high temperature should be allowed or made to escape above, and carries them down to be rebreathed by the occupants.

In the Houses of Parliament fresh air from the courtyard entering the basement is there warmed by steam pipes, whose heating surface is increased by vertical flanges; thus warmed it passes upwards by four large circular shafts into the space beneath the grated floor and risers of the seats, through which it flows into the house. To adapt the temperature of the incoming air to the needs of the ever-varying number of occupants, an attendant watches a thermometer in the house and regulates the heat by covering a greater or less surface of the steam pipes with cloths when the air is too hot, and uncovering them again when the house is empty or cool.

The hot foul air from the house ascends through the perforated glass ceiling into the roof, from which a channel conducts it down to the basement of the clock tower, where the flue of a large fire provides a powerful exhaust, so powerful that 1,500,000 cubic feet have been known to be passed in an hour.

The pollution of the air by the products of combustion from the gas lights is avoided by their position above the glass ceiling. When there is no occasion for warming the air, the exhaustion of the fire in the clock tower carries on the renewal of the air just as effectively, and in very hot weather the incoming air is cooled by being passed over ice in the same way as it is warmed at other times by the steam pipes.

In the expansion of compressed air an amount of heat is absorbed equal to that which was given off in the act of compression. This has been utilised in the New Zealand meat trade, the carcasses being kept at a temperature only just above freezing from the date of killing to that of leaving the stores in

Cannon Street. In 1889 I proposed the application of the same principle to the Houses of Parliament, and I cannot see why ventilation by means of *cooled* air should not be employed in summer as regularly as that by *warmed* air is in winter in public buildings, churches, theatres, and the like.

The plan adopted in the French legislative chambers is somewhat different. The exhaustive or motor power is obtained in the same way, but the air, instead of being drawn from the courtyard, is brought down from the top of a tower sixty metres high, and warmed in a chamber at its base. It then enters the house by openings along the cornices of the ceiling and the capitols of the columns, while the foul air is extracted through and near the level of the floor by an exhausting furnace and flue.

In Dr. Boehm's system of ventilation there are in the basement three chambers or flues, one above the other, distinguished from below upwards as the cold air, hot air, and mixing chambers. In the former the air admitted freely from outside is or may be strained, washed by water spray, or cooled by ice. In the middle chamber it is raised to a high temperature by hot water or steam coils. This chamber receives its air from the first, while both hot and cold-air chambers communicate with the last, or mixing chamber, from which the building is supplied. All these channels are under complete control, so that by mixing the hot and cold airs in due proportion, any desired quantity, temperature, or degree of humidity can be obtained. The movement of the air both in the inlet and outlet flues is determined by powerful fans, but a peculiar feature of Prof. Boehm's system is that the apertures of inlet are at the ceiling in winter and in summer near the floor, since in the one case it enters at a higher temperature than that of the room and tends to cool and fall, while in the other it is at first cooler and rises as it gets warmed. The outlets are placed conversely to the inlets, and all apertures are so arranged as to produce as far as possible diagonal currents through the room. The foul air is expelled at a part of the building remote from the fresh-air intake by a fan worked by the same engine and at the same speed as the propeller. The Opera House presents in its simplest, and the Town Hall in a far more complex form from the number and variety of apartments to be served.

The Maddison Square Theatre, Montreal, is a good example of artificial ventilation. The air enters by a tower, is filtered through a canvas bag forty feet long, forced into the house by a fan at the foot of the tower, and drawn out by one in the roof. Doors and windows are closed. The air is warmed in winter by steam, and cooled in summer by ice in the cellar. It

enters the theatre by pipes under the risers and in front of the footlights with a velocity of 2½ feet per second. The outlets are chiefly under the balconies. All the gas burners except the foot-lights are enclosed in glass and ventilated upwards, so that the products of combustion are carried to the roof. The cubic capacity of the building is 90,000 feet; it seats 650 persons, and the allowance to each is 1500 cubic feet per hour. The air is said to be as sensibly pure after a performance as before.

The greatest difficulty in the ventilation of most churches, whether the incoming air be warmed or not, is the cooling in the lofty roof, and consequent descent of the foul air rising from the mass of worshippers and gas lights. This has, however, been completely overcome by Professor Fischer in the Memorial Church at Berlin, which is built on the plan of St. Paul's Cathedral, but is one-third smaller in all its dimensions, by the simple device of keeping the dome at a considerably higher temperature than the body of the church, by series of hot-water coils concealed from view, in increasing numbers from its base to its summit. There are none below except between the double doors in the entrances. Fresh air, warmed in winter, is admitted through channels in the walls, sixteen feet from the ground, and deflected downwards by a projecting moulding. The lighting is by electricity. Whatever the size of the congregation or the external temperature, that of the building is constantly maintained at 60° F., and the air of a uniform purity.

The warming and ventilation of private dwellings is essentially the same in principle as that of the Houses of Parliament adapted to each separate room. The kitchen fire, the only one in the house, is kept burning day and night, and acts, like the furnace in the clock tower, as an exhausting power. The fresh air enters the house beneath the treads of the stairs, having been warmed in cold weather by a hot-water apparatus in the basement, and is admitted into the rooms over the doors and elsewhere. From openings around and in the ceilings, the foul air passes to a chamber in the roof, and down a channel to the bottom of the exhaust shaft. No separate fires are necessary, and in some houses the windows are not even made to open, effectually obviating the entrance of dust.

In large buildings, containing many apartments, hot-water or steam pipes may be so arranged as to subserve ventilation as perfectly as when heating is effected by means of warmed air. In each room the pipe is coiled in one or more boxes, into which fresh air is admitted by channels beneath the floor, and from which it escapes through the open ornamental work forming the sides of the box. In the larger rooms one or more coils may be made capable of disconnection from the general system so as to

regulate the amount of heat, the fresh-air inlets being left open or closed as desired.

But for private houses it would be hard to improve on the apparatus patented by Hermann Liebau, of Rodenburg, near Magdeburg, which in the form of, and serving as an ordinary kitchen range, not only supplies hot water for domestic purposes and baths, but by means of hot-water pipes and coils will ventilate with warmed air ten to twenty or more rooms, hall passages and stairs, maintaining a uniform temperature of 60°—65° F. throughout in the coldest weather, at a consumption in winter of a half to one cwt. of coke, no other fire being needed in the largest house. In summer the pipes are shut off by valves and only the range and hot-water service used with a proportionate reduction of fuel.

Summary of Chapter IX.

Heat is propagated by **conduction** in all matter solid, liquid, or gaseous, though in different degrees, and by **convection** in mobile matter, *i.e.* liquids and gases. **Radiation** takes place in vacuo and in air, obeying all the laws of the radiation of light, including reflection (and refraction). It does not warm the *space* it traverses, its intensity is directly proportioned to that of its source and inversely as the square of the distance. When falling on a body it is partly reflected, partly absorbed. Matter is **diathermanous** or **athermanous** to radiant heat as it is transparent or opaque to light. Radiant heat falling on solid bodies or passing through diathermœnous bodies is converted into ordinary dark heat. Radiation and absorption are equal.

Black or white, rough or polished surfaces, naked or jacketed stoves, pipes, &c., glass screens or roofs and other contrivances are employed to utilise these properties of heat to the utmost.

Quantity of heat must be distinguished from **intensity** or temperature, which is indicated by thermometers, whereas quantity is measured in calories or units. In England the unit is the amount of heat required to raise 1 lb. water 1°F., on the Continent 1 kilogram 1°C.

The heat of combustion, or that given off in the complete

oxidation of the C and H in 1 lb. of fuel into Co^2 and H_2O is in English units for wood about 3,000, coke and charcoal 10,000–12,000, coal average 13,000, and petroleum 20,000, hydrogen 62,535. But even under the best arrangements a large part is lost. So with the air required (or the oxygen × 5), the amount is found in practice to be nearly double the theoretical volume. Radiant heat as from open fires warms the walls and objects rather than the air, through which, after conversion into dark heat, it is propagated by convection, as the heat from hot-water pipes, &c., is entirely. **Closed stoves** in body of the room are most economical, very little heat passing up chimney. **Open stoves** are the reverse, but Galton's are the least wasteful. Stoves may be made to subserve ventilation by being enclosed in a jacket or outer case the intervening space communicating with the open air and that of the room. **Slow combustion stoves** are unwholesome, the deficient supply of air leading to incomplete combustion and formation of CO. A higher temperature is obtainable by Perkins' system of hot-water pipes under pressure, the boiler being a coil of the pipe inside of the furnace, than by low pressure systems in which the water in the boiler cannot rise above boiling point and that in the pipes is much lower.

Ventilation by warmed air is the ideal for public buildings and is easily adapted to ordinary houses. The system as adopted in the Houses of Parliament is rude, but those of several German engineers are nearly perfect.

QUESTIONS ON CHAPTER IX.

1. Under what circumstances is carbon monoxide likely to be found in the air of a room? What are its effects on the human body? 1890, A.

2. Explain the principles of construction of an ordinary fire-place, and state its advantages and disadvantages. 1892, A.

3. Describe and compare the action of ordinary fire-places and hot-water pipes in warming and ventilating rooms. 1894, E. 1895, A.

4. Describe the principles upon which hot water is generally supplied to bath-rooms, &c., and explain the reason why such an arrangement may be attended with danger. How can this be avoided? 1894, A.

5. Compare the merits and demerits of open and closed fire-stoves. Why do the latter require water to relieve the dryness of the air, which the former do not? What is the cause of the smell called "burning the air" when closed stoves are over-heated?

6. Contrast the advantages and drawbacks of low pressure and high pressure in warming by hot water or steam pipes. Describe Perkin's system and the method of filling the pipes.

7. What are the objections to closed stoves as means of warming dwelling-rooms? Describe any two forms with which you may be familiar, and point out their respective advantages and disadvantages. 1896, A.

8. Distinguish between radiant and obscure heat in their action on the air and on surrounding objects.

9. Why does a greenhouse without artificial heat become warmer in cold frosty days when the sun shines than in warmer days when cloudy?

10. State the laws of radiation, reflection, absorption, conduction, and convection of heat. Explain the different behaviour of a wall when whitewashed and when tarred or painted black.

11. Compare the heating power of wood, coal, oil, and gas. What are calories, English and Continental?

12. Why is the non-luminous flame of a Bunsen burner hotter than that of a common gas-burner consuming the same quantity of gas? What is the explanation of the high luminosity of the electric light, the oxy-hydrogen and limelight, and the Welsbach burner?

13. What are best forms and positions of boilers in relation to the furnace? Why does a saddle boiler heat faster than a kitchen side boiler, and a tube boiler fastest of all?

14. Discuss the causes of smoking of chimneys, and the best means for preventing it?

15. What is meant by furnaces consuming their own smoke? What are the economic and sanitary advantages?

16. What substances besides smoke are given off by coal fires? What are their effects on animal and vegetable life, on buildings, &c., and are they in any way prevented by "smoke consumption"?

17. Does the asbestos in a gas stove add to the heating power, and, if not, what advantage does it possess beyond the appearance or resemblance to an ordinary coke fire?

18. Compare, in respect of the heat evolved, and the amount and nature of the products of combustion for the same candle-

power, electric lights (arc and incandescent), acetylene, Welsbach, regenerative, Argand and fish-tail or bat's-wing gas burners, petroleum with round and flat wicks, colza oil, stearine and tallow candles. On what does the economy of the Regenerative and of the Welsbach burners depend?

CHAPTER X

House Drainage and Closets, Etc.

The first and fundamental maxim of house sanitation is, that there shall be complete interruption or disconnection between the pipes and drains within and without the house. All wastes from baths, lavatories and sinks, and rain-water pipes should in fact end in mid-air, *i.e.*, some inches above a trapped gulley, so that there shall be no possibility of foul air gaining entrance. Some architects would dispense with traps to waste pipes, but this is not wise since the interior of such pipes is apt to become foul and to infect the air which is drawn in by the warmth of the house. To prevent this a cast lead "S" trap, with a screw cap at the knee, by removing which it can be cleaned out, is indispensable in lavatories and sculleries where soapsuds, grease, hairs, &c., are apt to choke the pipe; further the bend should be wide enough for the passage of a brush or a wire. Each basin should have its own trap, for one common to several must be too large to be flushed by the discharge from a single basin, and become a reservoir of foul water and air.

In the upper floors several wastes may conveniently be made to discharge into a hopper head of a three-inch stack pipe, provided this too be not connected with the drain (Fig. 10).

Rain-water pipes may be thus utilised, but the practice of turning them to account as drain ventilators is thoroughly bad. Their upper ends are generally too near the windows to permit of their being so used with safety. They should end below with a shoe a few inches over a gulley, and a wire cover will prevent birds from building their nests in the hopper.

The points to be observed in laying house drains are the alignment, gradient, and jointing of the drain pipes, and the complete disconnection of the parts within and outside of the

dwelling, *i.e.*, of the part communicating with the sewer, and that connected with the traps, water-closets, baths, sinks, &c., inside the house. It is obvious that the lines should be as straight and the junctions as oblique as possible. If corners must be turned, it should be by a wide curve, not a right or even an obtuse angle.

Means of access should be provided to every straight section of drain for the easier removal of obstructions; manholes, or where the depth from the surface is not more than two feet, a shaft over a gulley large enough for a man's arm to work in, and to introduce the jointed rods, will answer this purpose.

To prevent deposit the drains should be not only straight, but small; four to six inches is large enough for an ordinary house, and nine inches for a hotel or hospital. The gradient should be much steeper than in the case of sewers, not less than 1 in 40 for a 4-inch pipe, of 1 in 60 for a 6-inch, and 1 in 80 for a 9-inch, but short drains may have a fall of 1 in 10.

Glazed earthenware pipes are usually employed; they should be free from roughness or inequalities on the inner surface, and in jointing good cement only should be used, but care must be taken while making the joint tight that the cement is not forced through so as to form a "feather" inside, which will inevitably lead to a deposit. Pipes have been patented in which the lengths are connected by a partial ball and socket joint instead of a mere flange; they are almost water-tight without luting, and admit of being laid in a gentle curve.

Wherever junctions are likely to be required specially constructed lengths should be introduced, with branches closed by a cap. Tributary drains may then be attached without disturbing the main drain.

Drains should be laid in concrete within the house, and in well-beaten clay outside. In all cases a bedding of concrete is expedient. Some pipes are made with a foot, which adds greatly to their steadiness. In passing through a wall care must be taken that the pipes are not crushed by sinking of the building. Workmen are not to be trusted, for they are apt to lay them without luting, or even to leave wide gaps, and to effect junctions by simply knocking a hole in the side of a common pipe. Escape of sewage from careless laying or from sinking and breakage of pipes in the basement, by which the foundation is converted into a huge cesspool, is of frequent occurrence in houses of all classes; if such an accident be discovered the whole of the polluted soil should be dug out, replaced by lime and carbolic acid, and then covered in with concrete or asphalt. All drains within or in close proximity to the

house should be bedded in concrete for at least one foot in every direction, and the house drain must be not only shut off from the sewer by a trap with a good water seal, but ventilated at each end so that there may be an uninterrupted flow of air through it from the street end to the ventilating shaft at the head.

Between the part of the drain in the house and that in connection with the sewer there should be a complete break ; in large buildings a manhole, and on the further or street side of this a trap, and in smaller ones an intercepting trap, *i.e.*, one open above to the air and covered only by a grating (Fig. 8).

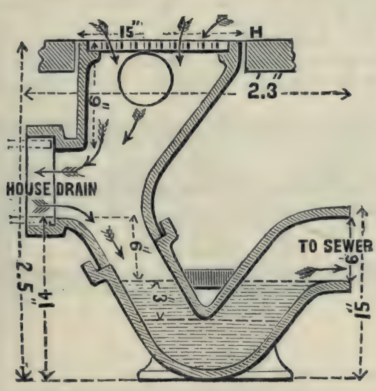


FIG. 8.

In large establishments, the drains and pipes from all parts should be made to meet in a common interception and inspection chamber, as in Fig. 9, which shows Bolding's Kenon in plan. The floor is of glazed stoneware, in as many segments as may be necessary, and with a middle and lateral channels, all open and adapted to receive pipes of any size and at any angle required. It is closed in by an air-tight cover.

If the distance between the manholes be considerable, one or more "lampholes" may be interposed. These are vertical pipes by which a lamp may be let down into the drain, when by looking along it from either end, the position of any obstruction may be ascertained.

In large houses there should be one of these chambers at each end of the drain to permit of its being inspected throughout, and also at any points where it receives branch drains from other parts of the premises or a change in its direction is necessary. But such should never be within the building, or if absolutely unavoidable they should be closed air-tight with cement, since no lid can be trusted in such situations. From the head of the drain, or the furthest chamber, a four-inch ventilating pipe, of cast-iron with well-leaded joints, should also be carried up outside the house, of the same calibre throughout, to some feet above the eaves, the higher the nearer it is to any windows; if it be attached to a chimney stack there is a risk of the foul air being drawn down an unused flue.

The soil pipe should in like manner be carried up full size and with the least possible deviation from the perpendicular to some height above the roof, foot ventilation being effected in one of

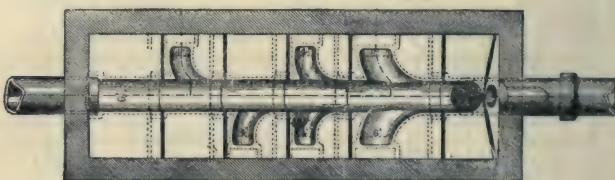


FIG. 9.

several ways according to circumstances. (1) The best plan is to disconnect it from the drain in a special gulley to which air has access through a grid, but which is itself shut off from the drain by a trap. There will thus be a free circulation of air in the soil pipe upwards from the aspirative action of the wind, and in some positions further aided by the warming effect of the sun's rays, and a complete renewal of the air from above downwards whenever a flush of water passes down the pipe. (2) When for any reason the foot vent is considered objectionable, the disconnecting gulley may be removed to a convenient distance provided the vertical and horizontal sections of the pipe are connected by a gentle curve. (3) In smaller houses, where there is little or no room for such an arrangement, the soil pipe may be made continuous with the house drains, superseding the special ventilating pipe. If its connection with the drain be made in a small manhole or chamber, a simple intercepting

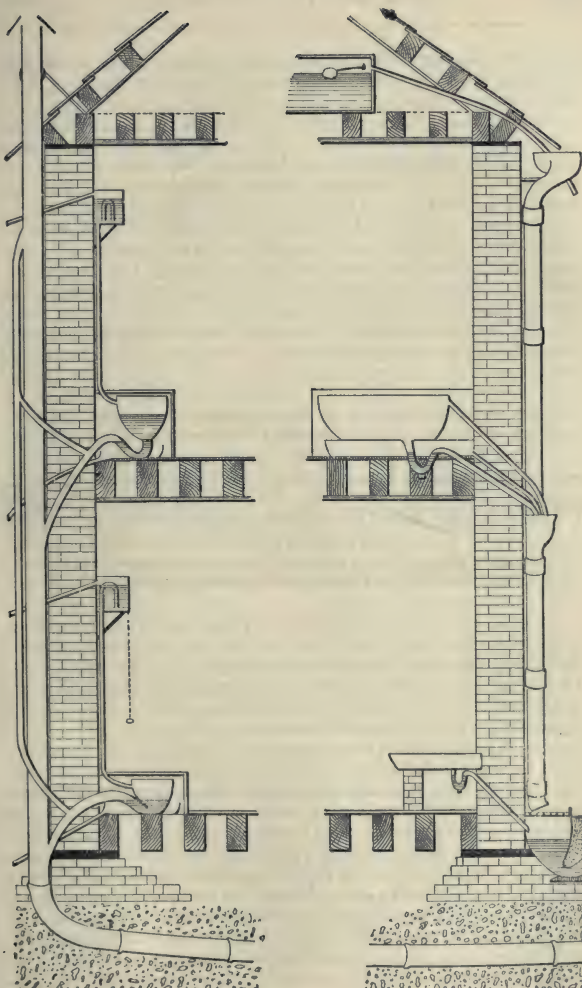


FIG. 10.

gulley at the sewer end of the drain will permit of inspection and removal of obstruction without taking up or breaking open the drain.

Whether the soil pipe be continuous with the drain and serve as an outlet or be disconnected and a separate ventilating pipe be provided, there must be an inlet or "foot vent" communicating with the interception chamber nearest the sewer, in the form of a dwarf pipe or shaft, which may be built into the front or area wall. It is usual to fit the mouth, which is generally in the face of the wall, with a mica valve so as to oppose any escape of foul air by a reversal of the current ; but such valves easily get clogged with dust, either ceasing to act as intended or preventing the ingress of air, and if not they may be kept closed by a down draught so long as the wind blows from certain quarters, when without them the current would be simply reversed (cf. p. 197, case 6).

A modification of this system finds much favour in America and satisfies the objection of some persons to an inlet near the ground and doors, but involves an excessive amount of friction.

In it the house system is intercepted from the sewer, but the soil pipe, instead of being ventilated at the foot, forms one leg of a siphon, which, passing under the dwelling, is carried up outside the opposite wall to a somewhat greater height above the roof. The soil pipe is surmounted by a downcast ventilator and the other or longer by an upcast, so that a current of air is constantly maintained in the same direction descending the soil pipe and ascending the other.

In some towns where the separate system with tubular sewers is adopted, these are ventilated by a pipe carried from the branch drain up the front of the house alongside of that which ventilates the house drain, a siphon trap being interposed between the junctions of the two with the branch, so as to shut off the house drains from the public sewers.

Mr. Weaver, almost alone among sanitary engineers, dispenses with all traps in the course of the drain, which he carries without interruption from the communication of the drain with the sewer to the summit of the soil pipe on the roof. In his system the public sewer is ventilated by means of the house drains, and it would be well enough could we be certain that the soil pipes were always and absolutely free from the slightest flaw ; otherwise it is undoubtedly dangerous. In this case there must, of course, be a good and efficient trap between the closet and the soil pipe, and all wastes must be disconnected with the greatest care.

The necessity of having soil pipes open at the foot will be clear, if one reflects that there can be no up-current of air in a

pipe closed by a water seal below, though open at the top. Soil pipes should not be built into a wall where they may be pierced by nails, still less should they be inside the house, for the warmth of the interior of a dwelling will suck the foul air through any weak point in the joints.

Soil pipes are often made too large, whereas the smaller they are the easier are they cleaned by a descending flush. For ordinary houses three inches is ample, and four inches is enough for a series of three or four water-closets, one above another, in the largest hotels. They are sometimes made of drain pipes, which, though durable, are always liable to leakage at the joints. Cast-iron with lead joints are better, though they rust away in time. Barff's iron is nearly imperishable, and is probably the very best material. Junctions with branches from the closets must be made by interposing sections of cast lead.

Lead is undoubtedly the best material in virture of its durability and imperviousness, but if such pipes are to be carried to the roof the cost is a consideration. Lead soil pipes if in positions where they may be exposed to wanton or to accidental injury should be protected by being encased in a cast-iron pipe to a height of six feet from the ground. They are drawn in one piece and tested, by being closed below and filled with water, which soon betrays any crevice in the metal. Lead is apt, however, to corrode in time. It is scarcely necessary to observe that no waste pipes should enter the soil pipe, much less should the overflow pipe of a cistern.

Mr. Norman Shaw and others have attempted to supersede ventilation, as above described, by air disconnection between the pipe from the water-closet and the upper end of the soil pipe, which is surmounted by a hopper head, dispensing even with a siphon in the former, but this plan is open to serious objections, since the effluvia from the soil pipe escape below the windows, and, if there be no siphon, are also certain to be drawn into the house.

Traps are bends or chambers in the course of a pipe, which, always retaining a certain quantity of water, interpose an obstacle to the passage of foul air in the form of a water seal. Their number is legion, but most of the patterns in vogue are more or less objectionable. Too much reliance is placed on traps by the public and by builders, who forget that water alone cannot resist any pressure of air; hence the necessity for disconnection and the ventilation of the sewers. Secondly, water absorbs foul air from below, and gives it off again above, even if the water in the trap be not originally foul. And lastly, when two or more

wastes enter a single pipe, then called a stack pipe, a flush descending from above, breaks into a dense spray, which acts like the plunger of a piston, and, since fluids press equally in all directions, it will siphon the water out of every branch as it passes with a gurgling sound. To prevent this a small pipe should be attached to the lowest branch on the near side of the trap, and being joined by similar pipes from each branch above should enter the stack above the highest in the series (Fig. 10).

The first requisite of a good trap is that it shall be self-cleansing, that is, that a moderate flush shall entirely renew the charge of water contained in it, together with any solid accompaniments. Tried by this test nearly all existing traps are failures. Bell traps may be dismissed as utter delusions and worse than useless. No traps with square bottoms can he self-cleansing, though permissible as yard-gulleys, and in streets where much solid matter has to be kept from entering the drain or sewer. In short, we are reduced to the simple siphon or one of its modifications, as Hellyer's V or anti-D trap (Figs. 11 and 12), which is the trap

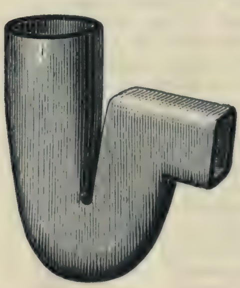


FIG. 11.

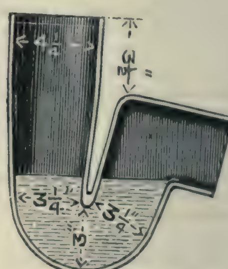


FIG. 12.

for water-closets, since it is not only self-cleansing, but the knee or upper side of the further curve is so planned as to prevent the collision and lodgment on its surface of solid fæcal matters. The D trap always associated with pan closets is an abomination (Fig. 13). It is perfectly true that, as plumbers urge in its favour, it can neither be forced by air pressure from below nor unsiphoned in the way we have described, but this is owing to

the fact that the water in it can never be completely changed by any number of flushes, and is consequently always foul. Further than this, if the dip pipe become corroded it ceases to be a trap at all, and this accident cannot be discovered except by its effects, perhaps only guessed when too late. The old-fashioned privy was of necessity detached from the house, but water-closets, being less palpably offensive, are placed in the most unsuitable positions, where either there is no ventilation possible or the closet is ventilated into the house. An open window in a closet on a landing will not serve as an exit for foul smells, but as an inlet carrying them, though diluted, into the house. With its window open such a closet becomes in cold weather and at night the chief source of fresh (?) air for the upper rooms.

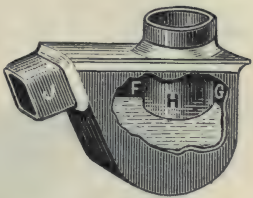


FIG. 13.

The **Closet** should, whenever possible, be "air disconnected" from the house. In the smallest class of houses no place is better than just outside the back-door, to which its own may be at right angles so as to avoid needless exposure to cold and wet in going to and fro. When it forms a part of the building it should not only be itself freely ventilated by inlets and outlets, but it should be cut off from the house by an ante-room with opposite windows, which should be always more or less open. This passage may be used as a lavatory, but the more it resembles a verandah the better.

Closets may be divided into four classes, the hoppers, the pan-closet, valve-closet, and flush-out. The hopper commonly supplied to servants' water-closets and the humbler class of houses is a simple funnel to which an S trap is attached. From its tapering form and the abruptness of the siphon bend the sides are always coated with filth, while the last charge or two of fæces and paper may constantly be seen at the bottom waiting to be pushed over the arch by succeeding ones. Nothing but daily manual labour will keep these pans clean, and this is not likely to be bestowed on them by the classes for whose use they are supposed to be adapted.

The pan-closet still found in a great proportion of respectable houses is a far more complex apparatus, but not less objectionable (Fig. 14). A porcelain hopper called the "receiver" is closed below by a copper "pan" forming a hinged valve worked by the

same "pull" that lets in the water, and also providing a water seal. The receiver with its pan is let into a larger hemispherical chamber called the "container," and the whole machinery is completed by a D trap. The interior of the container is always foul as is the D trap, several pounds of old hardened excrement being generally found on their sides after a few years' use.

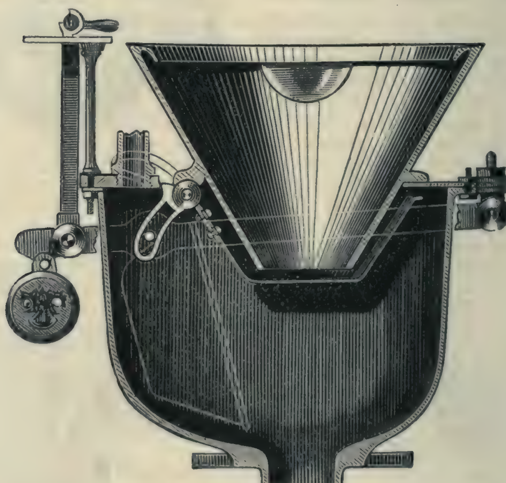


FIG. 14.

The foulness of the hopper is conspicuous and can be removed; that of the pan-closet is concealed from view, and cannot be reached except by taking the mechanism to pieces.

In the valve-closet the container is done away with; the pan is exchanged for a flat valve fitting so accurately as to be water tight. The pipe then descends vertically to the floor, and is connected with the soil pipe by a siphon bend, or the vertical pipe is dispensed with, and the valve opens at once over one end of a trap in which the elbow of the siphon is reduced to a mid-feather. Bolding's Simplex is a perfect valve closet, but Tylor's

and others are nearly as good. In the best of these the overflow pipe from the basin is trapped where it enters the space below the valve, which is also ventilated into the ascending part of the soil pipe. Valve closets are free from all the defects incident to common hoppers and pan-closets, but they are apt to get out of order, and are therefore unsuited to houses where there is any probability of neglect or carelessness (Fig. 15).

Wash-out closets (Fig. 17), to which Messrs. Jennings and Bostel have given special attention, are, like the hoppers, valveless. In

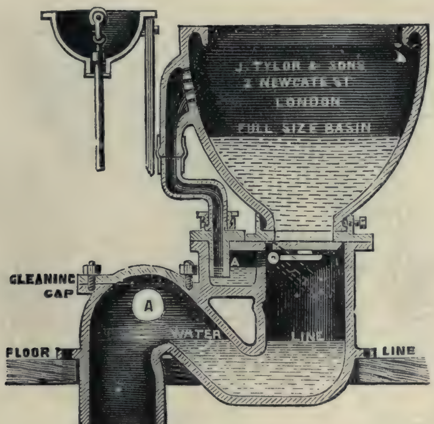


FIG. 15.

the earlier editions of this work, I was inclined to regard them with favour, but a longer practical experience of their action has led me to alter my opinion. The standing water is too shallow to cover the stools, or, if not, the ascent to the outlet is too steep for a single flush to clear the basin. But even if these defects be overcome, as they seem to be in some of the newer paterns, there is another inherent in the type. It is that, whereas in other closets, hoppers or valves, the full force or head of water bears directly on the contents of the trap, clearing it out with a single sweep, in the washout it is broken by the horizontal floor of the basin ; so that, though the cistern may be six or eight feet above the seat,

the actual "head" which bears on the trap is represented by the twelve or eighteen inches between the basin and the bend, in which each charge of fæces and paper will generally be found to lodge until pushed on by a succeeding one which remains there in its turn.

The "plug closet" of Mr. Jennings is open to all the objections incident to the wash-out together with the tendencies to run dry attaching to the valve.

For servants' w.cs, and indeed for all rougher use, the improved or broad hoppers are the best. They are made also

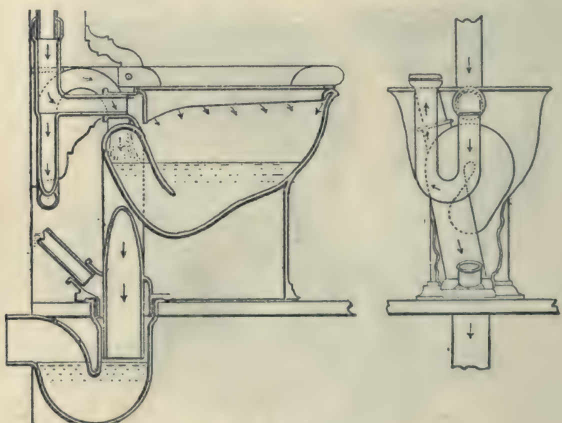


FIG. 16.

so strong as to be suited for the poorest class of tenements: the only fault being the very limited *surface* of standing water which renders fouling of the sides inevitable, and hand cleaning necessary. All attempts at extending the area of water have been confronted with the difficulty of evacuating it by a single flush.

Wash-out and hopper closets may be safely used as slop sinks, which others cannot be, unless the handle or pull be kept up while the contents of the pail are being poured down; and even then water is apt to find its way into the space beneath the seat, especially if the overflow should be choked by the ingress of solid matters. To provide against such accidents a "safe" or tray of

lead or zinc should be fixed on the floor under the closet, with a waste or outlet in the form of a "warming pipe," untrapped, but closed at its outer end by a flap valve to exclude the cold air.

With wash-outs and hoppers the only precaution required is that the mahogany seat should be hinged like a lid and a second leaden or porcelain top fixed beneath it. The seat is then to be raised while the basin is being used for emptying slops, and any splashing wiped up afterwards.

For cleanliness and simplicity, "Pedestals" or short hoppers, in which all boxing, so apt to harbour dirt and vermin, as well

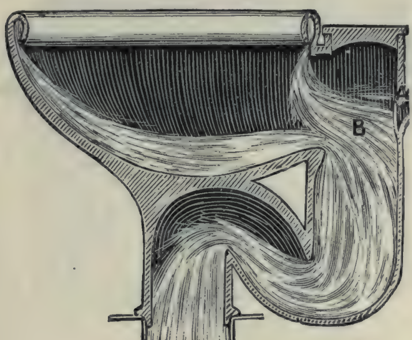


FIG. 17.

as cranks, &c., are done away with, are to be recommended ; a mahogany hinged seat only being superposed on a massive porcelain basin, which may be made really artistic.

But the "Closet of the Century" (Jennings and Morley's patent) (Fig. 16), and Bolding's "Ladas," which is simpler in construction, seem absolutely perfect, combining the freedom from all mechanism of the hopper, with the area and depth of water in the basin of the valve closet, while by an ingenious and novel arrangement the discharge from the cistern entering simultaneously the basin and the down pipe behind it sets up a siphon action powerful enough to carry off the contents of the basin at one sweep, including even such heavy objects as pieces of metal, after which the basin and traps are refilled by a later flush. Unlike other valveless closets they cannot

be siphoned out by a pail of water suddenly emptied into the basin. The whole cost including cistern is £5.

In no case should the water for the closet be drawn direct from the cistern used for general purposes, but a smaller cistern should be provided for the separate use of the closet.

Water waste preventers are small cisterns holding about two gallons, and so contrived that the same pull which opens the outlet closes the inlet, and the entrance of more water is prevented until the handle is let down again. Fig. 18, taken

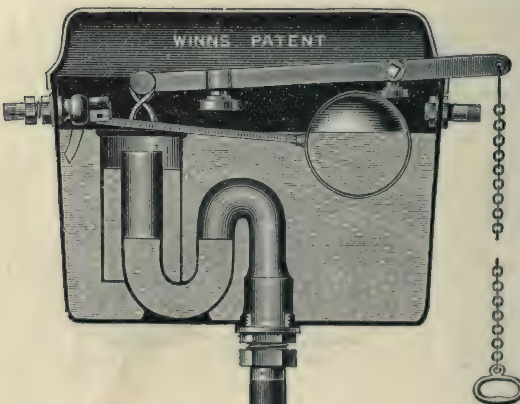


FIG. 18.

from Messrs. Bolding's catalogue, represents one of the best and simplest forms, giving an unusually powerful flush, and never getting out of order.

The regulator valve, Fig. 19, fixed in the course of the supply pipe under the seat, is much used with valve and pan closets, especially where there is no separate cistern. Though approved by the water companies, we cannot recommend it as a substitute for the water-waste preventers already described.

Latrines.—For schools, barracks, asylums, and other places where provision has to be made for large numbers of persons more or less mischievous, thoughtless, or ignorant, even the simplest forms of closets, such as we have described, are unsuited.

The most wholesome, and in every way the best arrangement, is to have the seats fixed over a long common trough, or over a series of nearly spherical hoppers, the wide open bottoms of which lead directly into a large horizontal pipe, the trough or pipe being always kept full of water, and cleaned out daily by an attendant, who raises a plug or opens a valve by which the trough communicates with the drain at the lower end, while he turns on water from a hydrant at the upper end or head of the trough. The very best pattern here shown is provided with arrangements for automatic flushing (Fig. 20).

Urinals.—We have alluded to the tendency of the salts and mucus of urine to form encrustations which soon become

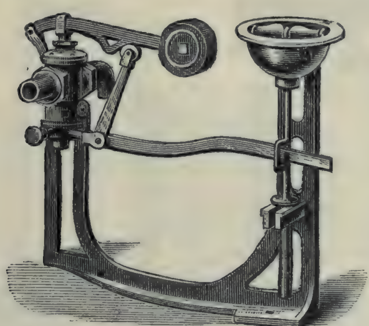


FIG. 19.

offensive and ammoniacal; only by having all surfaces with which the urine comes in contact well glazed, and the urine immediately diluted and carried off by a *continuous* flow of water can this be prevented, and urinals kept from becoming nuisances.

Lavatory Basins.—The ordinary way of emptying these by a plug is objectionable, for the soap suds, especially if the water be hard, floating on the surface, are left behind, and adhere to the basin. The "tip up" obviates this, but, as with the hopper closet, the back of the receiver should be perpendicular, to avoid splashing and adhesion of suds and dirt.

Scullery sinks are frequently the weakest points in the sanitary arrangements of the dwelling. The rough-hewn limestone

so often used is the worst possible material; glazed stoneware is infinitely better, being non-absorbent of greasy and organic matters and easily cleaned. The bell trap generally met with is worse than useless, being very prone to get choked if fixed, and sure to be removed by servants if not. The waste pipes should never communicate directly with the drain even though a siphon trap be interposed, but should be cut off over gulleys, or in an

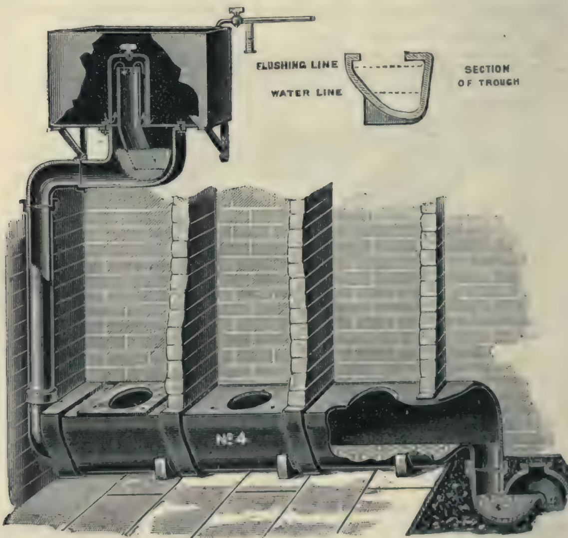


FIG. 20.

intercepting trap. An S or P trap with screw inspection cup for clearing, should be interposed between the sink and the termination of the waste pipe, for if this be open throughout its whole course, the air drawn in by the warmth of the house will be fouled in its passage, or if the gulley trap be not self-cleansing, effluvia from the deposit in the latter will be sucked up, as shown in Fig. 21. Messrs. Jennings, Bolding, &c., supply several excellent sinks which intercept solid bodies, and which can be

used as tubs for washing dishes or other purposes. Melted grease passing into drains congeals on their sides and tends to narrow or even to close the passage. To obviate this grease traps are designed, and should be used in all large kitchens. They are small intercepting tanks, or gulleys with a bucket always containing cold water. In them the grease and solid

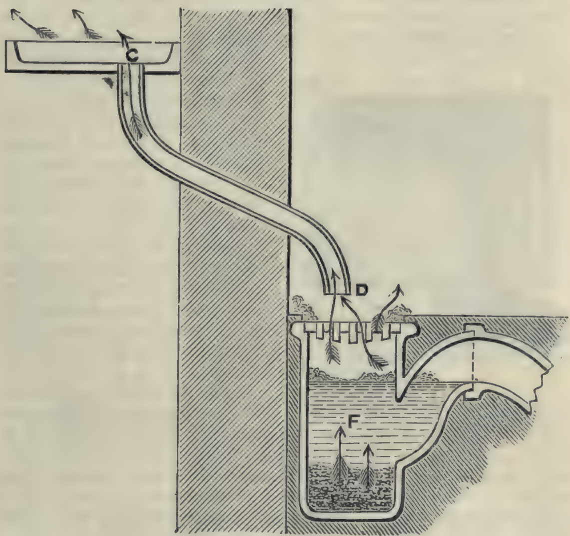


FIG. 21.

stuff collect and can be removed from time to time. Hellyer's and Bolding's are the best.

Flushing of House Drains.—Much misconception exists on this point. By flushing is meant a discharge of water such that the pipe or drain should *run full* for a certain time. No leaving taps open or holding up of closet handles will flush a drain ; such attempts are a useless waste. A single pail emptied suddenly will flush more effectually than a cistern full run off

slowly; and the merit of drains of small calibre, as we have recommended, is that they are flushed by a smaller volume of water. If the fall be sufficient, and solid bodies likely to cause stoppages are not allowed to find their way into the drain, flushing is rarely called for; but where an adequate fall cannot be obtained, or the drain system is extensive, flushing tanks are advisable.

Flushing tanks are of various kinds, mostly automatic, *i.e.* discharging themselves when full, but all are based on that of Mr. Rogers Field figured below (Fig. 22). Its principle, an annular siphon depending for its action on the peculiar form of the lip of the inner tube, is ingenious and simple. It may be fed by any small waste, as that of a drinking fountain, and when full it rapidly discharges the whole of its contents.

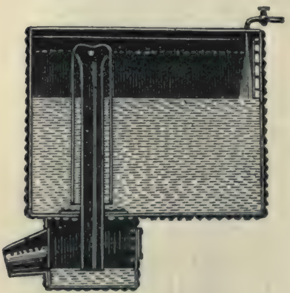


FIG. 22.

Field's tanks work well even with a mere drip, provided the water be clean, but where slop waters are utilised for flushing gulleys Adams' (Fig. 23) are greatly to be preferred.

It occasionally happens that the water runs quickly down the pipe without setting up the siphon action: should this be observed, it may be prevented by arranging an *inverted* ball cock that shall so soon as the level is reached *let in* a rush of water which never fails to put the siphon in action.

Testing Drains.—The strength and imperviousness of drains of any length should be tested so soon as they are completed, and also in the event of any doubt arising subsequently as to their competency, by securely closing the furthest end, and filling the whole with water. If, after several hours, no change is perceptible in the level of the water, they may be considered sound; if, however, it have sunk appreciably, the defective point must be sought and found. By increasing the "head" or height by fixing a vertical pipe at the highest point any desired pressure may be obtained.

To discover flaws in the drains and pipes within a building the various fittings, traps, closets, &c., must be separately examined, seats, casings, &c., being removed, so that every part

may be seen, water being run down each branch. The time it takes to reach the main drain outside the house is noted, as well as the rate at which it flows out. An incidental advantage of inspection chambers is that the water test can be applied at any time without opening up the ground or breaking the drain, the mouth of which may be closed by a plug of india rubber between two wooden disks brought together by a screw or by a rubber bag inflated by pumping in air or water. A wooden plug should never be used, for swelling when wet it is apt to split the pipe, if fitting tight enough to exclude leakage. Before applying this test to newly laid drains time should be allowed for the hardening of the cement and concrete, or the pressure of the water, due to the fall, will force the joints, and perhaps make channels in the bedding. Or smoke rockets may be burned at the foot by one person while another perambulates the building. The upper end of the soil or ventilating pipe must be closed by a wet cloth. Any leakage will be thus discovered. All doors and windows should be closed during the examination, and the warmer the house at the time the more delicately the test will act.

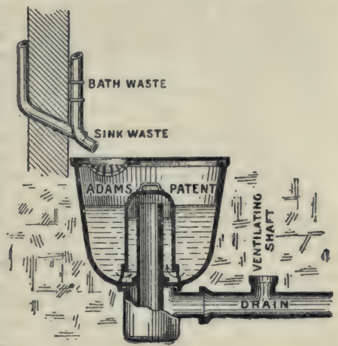


FIG. 23.

The "Grahtrix" and other bellows for forcing in the smoke are far more sure in their action than rockets, which may fail to show small leakages, from the absence of any pressure, gases, unlike water, being compressible. Smoke tests must be used for soil pipes and others above the ground-level; but for drains the water test is greatly to be preferred.

For short lengths of pipe chemical tests are sometimes used, consisting of a glass tube closed by a spring valve secured by gummed paper, and attached to a string for withdrawing it. This is passed through the trap, when the water sets free the cap, and, acting on the chemicals, causes the evolution of a large volume of pungent smelling gases.

Building Materials and Construction of Walls.

In selecting the materials, and in the construction of the foundations, the walls, and the roofs of dwellings, the first essential condition to be secured is dryness. A damp house is always unhealthy. The next is that the materials shall be bad conductors of heat, that they may retain the internal warmth in cold weather, and exclude the external heat in warm. A well-built house is warm in winter and cool in summer.

Every one who has worshipped in an iron church knows how the reverse conditions exist in such buildings: they are dry enough, but insufferably hot in summer, while incapable of being properly warmed in winter. Iron being a good conductor allows the passage of the heat from without inwards or from within outwards. Such buildings are, or ought to be, lined with boards and felt or slag wool, which are very bad conductors.

The relative conductivity of several building materials may be judged of by the units of heat transmitted per square foot per hour through a plate 1 inch thick, the temperature of the opposite surfaces differing by 1° F. For planks 1·37, plaster 3·86, brick 4·83, freestone 13·68, and for marble 22 to 28.

Thus, too, tiles make better roofs than slates, which though lighter are more easily displaced, and from their thinness and greater conductivity must be backed by boarding. For flat roofs lead is unrivalled in durability and soundness, but is too heavy for jerry building. Zinc, now generally used, as far lighter and cheaper, is very perishable and the seams cannot be kept water-tight.

A consideration of more practical importance is the porosity of the material and its consequent tendency to absorb moisture, which is taken up by the warmer air of the interior, and produces cold by its evaporation. To ascertain this a brick or piece of stone is thoroughly dried and weighed; it is then placed under water for an hour or so, taken out, wiped, and weighed again. The increase in weight shows the water absorbed. The percentage of their own weight absorbed by different building materials has been found to be as follows:—Malm bricks, 20 to 22; common grey stock, 10½; hard ditto, 7½; washed ditto, 4¼; brown paviors, 17; hard ditto, 7½; blue Staffordshire, 6·5; dressed ditto, 2·3; brown glazed bricks, 8·6; good sandstones, 8 to 10; Portland, 13·5; Bath, 17; Ransome's artificial stone, 12; Kentish rag, 1½; and granite, ½ to 1.

Newly built houses are always damp. A simple calculation will show, according to Captain Galton, that in a house in which 100,000 bricks have been employed, the water in the mortar, &c., will not be less than 10,000 gallons, all of which must be

removed before it can be occupied with safety. If, on the other hand, as sometimes happens, the bricks are used hot and dry from the kiln they suck up the moisture from the mortar too rapidly, and prevent its setting properly. The firmest setting of the mortar and adhesion of it to the bricks is obtained by dipping each brick separately into water, but of course a longer time must be allowed for such work to dry.

Brick being porous absorbs water from the ground as well as from the rain that beats on the walls. To prevent dampness from the first cause recourse should be had to several expedients, variously combined.

The level of the ground water should be ascertained by digging a hole of sufficient depth after a moderately heavy rainfall, or in wet weather. If this be within six or ten feet of the surface the subsoil should be drained. In impervious clays there is of course no ground water, but in gravels overlying clay it may be abundant and subject to great variations, which are worse than a fixed level even nearer the surface, since they cause movement of the ground air—the "ground respiration" of Pettenkofer,—and the entrance of this air charged with moisture and carbonic acid into the house every time the level of the water rises.

Under such circumstances at least, the whole area on which the house stands should be covered with concrete or asphalt. In all cases the foundations ought to be laid in concrete, and the space beneath the lowest floor freely ventilated by air bricks or openings in numbers sufficient to allow of a free through current of air; rotting of the joists and boarding will be thus prevented.

Below, and for some distance above, the ground line walls should be double, a space being left, and ventilated by air bricks. This is called a dry area. Also in every class of buildings damp proof courses should be introduced a little above the ground line. These are made with well glazed hard stoneware air bricks, which preclude the upward suction of damp from below. Scamping builders often substitute pieces of asphalt, felt, slate, &c., but these are useless shams.

A tolerable expedient which may be adopted in default of more effectual means in houses already built, is to excavate the soil around the walls, and apply several inches of asphalt to their outer surface, at the same time providing for the ventilation of the space beneath the floor of the basement by openings on opposite sides of the house into shafts of a foot square, if the construction of an ordinary area would be likely to endanger the stability of the edifice.

Not only is a hollow wall, in which the capillary attraction of the bricks for water is broken by the interposed air space, drier than a solid one, but it is warmer, air being a far worse conductor of heat than brick. Damp arising from the beating of rain on the walls is of course best prevented by the use of the least porous kinds of brick, but in old houses, especially in exposed situations, much improvement may be effected by washing the surface with a silicate solution. Projecting eaves under certain circumstances afford additional protection as does a covering of ivy; where this can be obtained the wall is most effectually sheltered from damp besides acquiring a picturesque appearance. Lath and plaster walls, and the space below the floor boards, may be stuffed with slag wool, which is fire, damp, sound, and vermin proof.

Walls may be rendered perfectly impervious to damp, and soft absorbent stones, as those used for decorative work of churches, preserved from perishing, by a free application of "water glass." The potassium not the sodium silicate should be used, and it should be had in the gelatinous or size like form which is easily soluble in hot water, though on drying it becomes as hard as glass itself. It may while fluid be mixed with pigments when it gives the appearance of encaustic tiles, and is much used in Germany for internal decoration as well as for the preservation of the exterior of public buildings though scarcely known in this country. Internal wall surfaces if freely coated with it are damp-proof and have the appearance of enamel, but brick and stone are not altered in colour or appearance if not more than can be absorbed is laid on.

Dry rot, so called, is a fungus, the mycelium of which penetrates the structure of timber, especially of the fir tribe, disintegrating it by a chemical action. It requires damp and darkness for its development, though for fructification it seeks the light, scattering its snuff-like spores. Prof. Polek, who has traced its life history, and has succeeded in cultivating it from the spore, confirms the belief that its ravages are almost, if not exclusively, confined to wood felled "in the sap," *i.e.*, in spring or in summer. If such wood cannot be entirely avoided, its growth may be prevented by keeping the basement and foundation dry, light and well ventilated. Arsenical and mercurial preventive solutions are highly dangerous, the only chemicals permissible being the products of coal tar.

INTERNAL WALL SURFACES.

The use of plaster of a coarse quality covered by a thin layer of a finer kind and then papered, is well nigh universal, but both

plaster and paper are open to objections. Plaster being porous absorbs the moisture of the internal air, and with it the foul organic matters exhaled in respiration. The absorption of watery vapour is rendered evident when we compare a varnished with a plastered wall, and notice how, when the vapour stands condensed in drops on the former, the latter *appears* dry ; while as to its power of absorbing organic matters we need only refer to a fact mentioned in a discussion at the French Academy of Medicine in 1862, that the analysis of the plaster of a hospital ward showed the presence of 46 per cent. of organic matter. White-washing does not remove or destroy, but merely covers this over and presents a fresh surface for absorption.

The best wall covering would be one perfectly impervious and which could be washed with soap. Parian cement nearly fulfils these conditions, but is costly and liable to crack. Paint is practically but not absolutely impervious and though washable will not bear much soap or rubbing. Where cost is no object, Lincrusta is admirable, being durable, impervious, and highly artistic : but Fisher's Permanent wall hangings are little inferior in any respect, washable, and actually cheaper than paint or high-class papers.

Enamelled tiles are impervious but ill adapted for most rooms, and the jointing offers lodgment for dirt.

Wall papers will probably never be superseded for general use, but they are, from a sanitary point of view, about the worst covering that could be conceived, especially when one is laid over another. They are absorbent and unwashable, and afford every opportunity for the adhesion of dust and dirt. Worst of all are the flock papers, and next those embossed or stamped.

Much has been written of late about arsenical colours in wall papers and their dangers to health. As secretary to the Poisonous Pigments Committee of the National Health Society, I had ample opportunities for obtaining information on the subject. No doubt some of the alleged cases of illness caused by such papers will not stand scientific examination, but many others are incontrovertible. Though the effects are frequently obscure, dyspepsia and general derangement of the digestive organs and nervous system, irritation of the mucous membrane of the eyes, and other symptoms of a like character have been indisputably traced to the presence of arsenic in wall papers. Some persons are much more susceptible than others. Papers of an inferior quality to which the colours adhere but loosely are the most dangerous : those, in fact, that are most used for bedrooms and for the poorer class of houses.

It is a popular belief that green colours only are arsenical, but

this is an error. No colour can be considered free without examination, and every colour can be obtained, even the brightest greens, without a trace of arsenic. Those made by Messrs. W. Wollams & Co. (not T. Wollams) were all absolutely free from arsenic, but many others shown by analyses to be highly arsenical were guaranteed free by the dealers. I made up a book of patterns taken from some 700 examined, arranged in pairs of similar tints and not unlike patterns, such that they could be in every case substituted for one another to please any taste, one of each pair being arsenical, perhaps highly so, and the other perfectly free from the least trace. Every colour, green, red, blue, white, &c., is there represented.

Mr. F. E. Matthews, formerly of Cooper's Hill College, called attention to the highly dangerous character of many of the cretonnes, so much in vogue, and the imitation Indian muslins. Of 44 samples of cretonnes which he analysed, none were entirely free from arsenic, and 20 were more or less poisonous, as were all the five muslins examined. One cretonne contained arsenic equal to 20 grains of arsenious acid, or white arsenic ($AS\ 2O_3$), in the square yard. Indeed, as he observed, there was often enough arsenic in the curtains and furniture covers of a modern drawing-room to give a fatal dose to a hundred persons. No colours were entirely free, but generally the blues and greens contained less than the reds, browns, and blacks. Several cases of poisoning occurred among the students of the college.

Though the quantitative analysis of arsenical pigments requires considerable manipulative skill, the presence or absence of arsenic may in most cases be established by Reinsch's test, which any one can apply by means of a small apparatus supplied at a cost of 8s. 6d., with instructions for its employment, by Messrs. Townson & Mercer, of 89 Bishopsgate Street Within. The accompanying reagents are sufficient for the examination of 50 papers.

No ill results have been shown to follow the use of arsenical or other poisonous pigments in oil paints, but distempers are often coloured with the same pigments, and are then at least as dangerous as the papers for which they have been proposed as substitutes.

A few words as to floors may not be out of place. Timber merchants cannot afford to keep deal boards long enough for seasoning; they consequently shrink after having been laid, and the gaps afford lodgment for dust and dirt, which when scarlatina or small-pox has been in a room may be actively infectious, besides being liable to putrefactive changes when damped by scrubbing.

Where parqueterie, or tongued boards are thought too costly the boards should be short and narrow, with surfaces and edges planed smooth, so as to admit of being accurately fitted, they may then be stained and varnished, or still better, treated with beeswax and turpentine, and polished. Such a floor is very easily kept clean by sweeping, or merely wiping with a moist cloth ; scrubbing, which causes damp and is a laborious and dirty operation, being quite superfluous.

Carpets, receptacles for dust and dirt of every kind, may then be dispensed with, since the floors are no longer unsightly, or may consist of comparatively small squares, not nailed down, and easily removed to be beaten outside the house.

Scarcely less essential to the healthiness of a house than the exclusion of effluvia and damp, is the free access of light and air, without which no place can be kept clean, sweet, and wholesome, to every part of the building. Dark stairs, passages, and corners, *culs de sac* and unventilated closets, are abominations, and there is no reason why everywhere, from the coal-cellars to the loft, should not be equally light.

Light is more needed in the kitchen and scullery than in the dining-room, and air more in the bed-rooms than in the drawing-room. The larder and dairy must indeed have a N. or N.E. aspect to secure coolness, but exclusion of the direct rays of the sun is then compatible with the freest admission of fresh air and diffused daylight. It is needless, I hope, to add that the nurseries should be the brightest, most cheerful, and airy rooms in the house ; but I also hold that box or lumber-rooms, house-maids' closets, and all places where anything dirty or damp is likely to be stowed away, should be so light that they cannot be put out of sight.

Summary of Chapter X.

There must be air disconnection between the house and the drains. All **waste pipes should be trapped** inside the house and end outside over gulleys. So should rain water pipes, which should never be used to ventilate drains.

Drains should be laid in straight lines with means of access at junctions and changes in direction, at proper gradients, 1 in 40 for 4 inch to 1 in 80 for 9 in., very short ones steeper, and bedded in concrete in and near the house. One **inspection chamber** at least between house drains and drain to sewer. **Soil pipe** must be outside the house, lead or strong cast iron, carried up to open above roof, and not trapped below.

House drains intercepted from sewer by trap close to inspection chamber and ventilated by inlet into this and outlet by soil pipe in small systems, or by special pipe at head of large ones; an automatic flushing tank is an advantage in such.

Traps should have a good water seal, not easily broken, yet be self-cleansing. When several are in proximity in horizontal or vertical series an antisiphoning pipe should be provided to each.

Gullies are not self-cleansing, being intended to arrest solids, but should be easily cleared or emptied by hand.

Water closets should be well ventilated, if possible not into house; conical hopper basins, pan closets with D-traps and wash outs are bad. Wide hoppers, valve closets and wash downs are good, the best are the newest siphon closets, the Ladas and Century. They should be supplied from a cistern not used for other purposes, or have their own on the siphon system.

Privy cesspits should be abolished, and earth closets or portable pails emptied daily on to garden ground are best for cottages and small houses in country.

Drains are best tested by water, but smoke test must be used to discover defects in soil pipes, &c.

In large country houses with water closets cesspits are permissible if at a distance from the dwelling, perfectly water tight and with pumps, &c., for distributing the dilute sewage on land.

Walls and Building Materials. Dryness being necessary to health, bricks or stones should be chosen that absorb the least volume of water. If the ground water fluctuate much or be near the surface it must be kept low by drainage; the site of the building laid with concrete, and damp proof courses inserted in the walls which should also be surrounded by an open area, well drained, or with "a dry area" or faced with cement. Double or hollow walls are good. Walls exposed to rain and storm may be rendered water proof by soluble silicates as "water glass," or protected by ivy. Interior wall surfaces should be made impervious in like manner, or by paint, or "washable" coverings as lincrusta, Fisher's or other substitutes for wall papers. The prejudice against impervious walls is based on erroneous notions. Wall papers lodge dirt and infection, and many pigments of all colours contain arsenic, and may cause poisoning. Dust is a fertile source of disease, and everything that retains it, as cornices, fringers, &c., should be avoided.

Floors should be laid without spaces between the boards, and be smooth and impervious, stained and waxed, with rugs or movable carpets. Light and air should be freely admitted everywhere.

QUESTIONS ON CHAPTER X.

1. Describe the construction of a pan closet and of a D-trap, giving sketches. Are they good or bad forms of sanitary apparatus? Give your reasons. 1884, A.

2. What are the conditions of a good house drain? How should it be ventilated? 1885, A.

3. Describe the dry earth system for the treatment of excreta. What are its advantages and disadvantages? 1885, A.

4. What means should be adopted for preventing (*a*) air, and (*b*) moisture from the soil from entering a house, and why? 1885, A.

5. Sketch and describe a good form of hopper closet. How should it be supplied with water? 1886, A.

6. Describe in detail, with sketches, the construction of a good valve closet. What are the arguments for and against the use of this form of closet? 1886, H.

7. Wherein do wash-out and wash-down closets differ? Of what type is the latter an improved form, and in what does the improvement consist? What is the great defect of the former, and is it insuperable?

8. Under what circumstances would you recommend the choice of wash-down or valve closets respectively? Can you name any patterns better than either?

9. What accident may occur in using a true siphon closet of the type of the Dececo?

10. Water-closets should not be supplied directly from the general cistern. Why is this enforced on sanitary and on economic grounds? Under what circumstances is danger likely to follow? Give a case in point.

11. Describe two or more types of service cistern for closets, giving your reasons for preferring one or other. What are the conditions that such a cistern should fulfil? Why are they called water waste preventers?

12. By what arrangement may the closet be supplied from the general cistern without danger to health?

13. What are the best positions for a closet in the house, to secure proper ventilation? What positions are inadmissible?

14. Describe the principles of the "Ladas" and the "Century," and point out their advantages over the best of the simple wash-downs and siphon basins.

15. Describe, with sketch, a "trough" closet for schools, public conveniences, and common lodging-houses.

16. What arrangement is necessary for keeping urinals from becoming offensive? and show why they should not, as a rule, be permitted in dwelling-houses.

17. What is meant by a disconnecting trap? What are its uses? 1887, A.

18. Distinguish between "interception" and "disconnection." Sketch a few simple forms of "disconnecting traps" and "chambers."

19. What are "lamp-holes" and their uses? Where should they and "disconnection" or "inspection" chambers be placed?

20. Describe, with sketches, good forms of "S" traps, interception traps, the "V" trap, and the grease trap. Distinguish between traps and gulleys, as regards their purposes and their forms. What arrangements should be made for manual cleansing of each?

21. What are the essential conditions of a good trap? What is meant by a trap being self-cleansing? What kinds of trap should not be so?

22. What points should be attended to in the construction of house drains? 1888, A.

23. What is the importance of a dry basement floor, and how should it be secured? 1888, A.

24. What is "dry rot," what timber is most liable to its attacks, what conditions favour its ravages in buildings, and how may it be prevented?

25. How are the water and smoke tests applied to drains? What are the circumstances under which you would resort to the latter, what its defects, and how can they be to some extent obviated?

26. How would you ventilate the drains of (1) a large establishment; (2) a good house in a street; and (3) a small one, with no forecourt?

27. What is the only permissible position for a soil pipe? How should it be ventilated (1) if single, and in the rear of the house? (2) if one of several? In the latter case, what provision should be made for the ventilation of the system of house drains?

28. What is the principle on which flushing tanks are constructed? Give sketch.

29. What points should be specially kept in view in the alignment, gradient, calibre, bedding, junction, and jointing of house drains?

30. Discuss the materials, calibre, jointing, and termination below of (1) soil; (2) rain-water; and (3) waste-water pipes.

31. Explain the various ways in which siphonage of water traps takes place, and how it may be prevented. Illustrate your answer by sketches. 1890, H.

32. Damp in houses is caused by rain beating on the walls and moisture rising from the soil. How may the latter be prevented, and the former remedied?

33. How would you determine the capacity for absorbing moisture of a sample brick? What is it for three or four of the kinds in most general use; also for limestones and granite?

34. What is water glass, and to what purposes may it be applied? Which is the better for damp-proofing walls, the potash or the soda glass?

35. Compare the sanitary advantages and disadvantages of the following materials for internal wall surfaces:—Distemper, paint, paper, match-boarding, lincrusta and other washable materials, and varnished papers.

36. Discuss the advantages and disadvantages, real or supposed, of pervious and impervious internal wall surfaces.

37. Contrast the sanitary advantages and drawbacks of the following materials for roofing:—Slates, Brosely tiles, lead, and zinc. 1896, A.

38. Given two similar houses with like arrangements for heating and ventilation, but one built of brick with tiled roof, the other of stone with slate roof: in which will it be easier to maintain an equable temperature in hot and in cold weather? What should be the relative thickness of the walls to secure like results?

39. Rooms in a slated roof with zinc-covered dormer windows are intolerably hot in summer and cold in winter. How may these evils be minimised? What is the special advantage of slag wool as a lining for roofs, lath and plaster walls, and floors?

40. What forms of closets are most suited to labourers' dwellings, factories, and schools? Under what conditions may they be expected to work satisfactorily? 1896, A. 1898, A.

41. If two or more closets superposed in as many floors are connected with one soil pipe, what inconveniences may ensue and how may they be avoided? Is it necessary to make the soil pipe larger than for a single closet?

42. Sketch the arrangements for the drainage of a two-storied house, including water closets, bath, and sink, and show the connection between the house drain and the sewer. 1899, H.

43. State the best position for a "damp-proof course" in walls, and name the various materials in general use, giving a careful description of the method of construction you prefer. 1899, H.

44. What is meant by siphonage? Explain how it affects the working of, water closets, and how it may be prevented? 1900, A.

45. What is the difference between a slop sink and an ordinary sink? 1900, A. What forms of closet render slop sinks needless?

46. Describe and illustrate by sketches the proper and faulty arrangements of the traps and waste-pipes of a series of lavatory basins. Is it a good plan to have a trap at the end of the waste-pipe common to the series, and, if not, why? Is it proper to connect the waste (*a*) trapped, or (*b*) untrapped, of a lavatory basin with the trap of a bath?

47. What are the best materials for (*a*) the floor of a sitting-room, and (*b*) that of a scullery? 1900, A.

48. What are the inconveniences and dangers of ill-fitting floor-boards?

PART III

HEALTH OF THE CITY

CHAPTER XI

POTABLE WATERS

Potable Waters are such as are fit for habitual use as drink either in their natural state or after having been submitted to such simple modes of purification as subsidence and filtration. The sources of such waters are the rainfall collected in tanks, natural springs, wells which are artificial springs, rivers, and lakes. They differ greatly in purity and composition, but absolutely pure water is almost unknown. Rain water collected in the open country is the purest, though even it takes up matters in its passage through the air, and in towns may be strongly acid. Some lakes furnish a water of high purity. All waters which have been in contact with the soil dissolve out from it numerous inorganic and organic substances; and rivers, especially when disturbed by heavy rains or floods, hold a large amount of insoluble matters in suspension.

Waters are described as hard or soft, hardness being the popular expression for the property of not easily forming a lather with soap. It is due to the presence of salts of lime and other alkalies and earths, which decompose the soap, forming with the fatty acids which it contains curdy insoluble compounds, and no lather is possible until the whole of the lime, &c., has been thus removed.

Hardness is again of two kinds, the temporary and the permanent; the former is removed by boiling the water, while the latter is irremediable. Temporary hardness is caused by the carbonates, dissolved in the water by the free carbon dioxide present in large amount in all waters which have permeated the soil, but thrown down when this gas is driven off by boiling. These carbonates constitute the bulk of the crusts which form in kettles and boilers, as is shown by the ease with which they are dissolved with effervescence by the weakest acids, as vinegar.

Permanent hardness is owing to the presence of sulphates, chlorides, and nitrates of the earthy metals, and is so called because these cannot be separated, as the carbonates are, by boiling.

Hard Waters, if their hardness be due mainly to carbonates and not excessive, are agreeable and wholesome for drinking, but they are all ill-adapted for laundry purposes, and still more so for personal ablution, if not boiled. They tend also to harden vegetable tissues cooked in them, and imperfectly extract the virtues of tea. The hardness of waters is estimated in degrees indicating the number of volumes of a standard solution of pure Castile soap in alcohol required to produce in the water a lather which shall be permanent, *i. e.*, shall persist for five minutes after agitation. The solution is such that each volume so used is neutralised by the carbonate of lime or its equivalents present in the proportion in this country of one grain to the gallon, and on the Continent of 1 part in 100,000; but since one volume of the soap solution is needed to make the lather after the others have been used up by the lime of salts, the proportion of these is represented by a number less by one than the volumes employed. Thus, if five volumes are required the hardness is 4°, and the lime salts four grains to the gallon. Temporary hardness is determined by deducting from the initial or total hardness, the value obtained by the application of the test to the clear supernatant fluid decanted off from the sediment, if any, after the water

has been boiled and allowed to stand, and which represents the permanent hardness. Dr. Clarke, to whom we owe this test, also invented a process for the softening of calcareous waters by the removal of the greater part of the carbonate, applicable on a large scale, as in water works. It consists in the addition of a definite quantity of "milk" of lime, regulated by the hardness of the water to be softened; and is founded on the fact that carbonate of lime, *i.e.*, chalk, is almost insoluble in water free from carbon dioxide, though soluble in that containing much in solution. When, then, a solution of fresh lime is added to such a water in the exact proportion indicated by its hardness, the lime combines with the excess of CO^2 to form a carbonate, which falls together with the original carbonate, the solvent power of the free carbonic acid being withdrawn, thus:

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O.$$

Ten-elevenths of the temporary hardness can thus be removed, but the permanent is not affected, so that the hardness of waters of 15° to 20° cannot, as a rule, be brought down below 2½° to 3°. It seems, at the same time, to remove many organic impurities. Maignen's "Anticalcaire" removes the sulphate as well as the carbonate of lime, reducing the permanent hardness, and entirely prevents the crusting of boilers. The hardest waters are those of the chalk, limestone, and dolomite, the last containing magnesia, and being permanently hard. Thus, Sunderland (dolomitic) water shows 30°, Chatham 24°, Croydon and Kent Company 20° to 21°.

Rain water is, of course, the softest, but as a rule, lakes yield waters of a very low degree of hardness; thus, Manchester water (Thirlmere) gives 2° to 3°, Bala lake only 0·28, and Glasgow water (Loch Katrine) 0·0.

In the moors and hilly districts of Yorkshire, &c., many large towns are supplied with water obtained by impounding the mountain streams near their sources, and by intercepting the rainfall of the high lands by embankments carried across the

valleys and gorges between the hills, thus forming artificial lakes. Liverpool, formerly supplied from wells in the red sandstone, has now an additional supply from the mountains of North Wales. No better water could be had ; but where mills and factories have depended on the rivers in question, at least a third is required to be returned as compensation.

Rivers and springs from other than limestone and calcareous formations vary much. The Thames, the New River, and the Rhine show 12° to 16°, the greater number of waters supplied to provincial towns 10° to 14°, but those of Edinburgh, Dublin, Exeter, Swansea, Whitehaven, &c., 1° to 5°. Rain when formed in the clouds is almost absolutely pure, but in falling through the air dissolves or takes up an appreciable though practically insignificant amount of impurity, especially in and near large towns. Thus the rain falling in a rural part of Scotland was found by Dr. Angus Smith to contain sulphuric acid (H_2SO_4) in the proportion of 0·0121 grains to a gallon, that in London 0·339, in Manchester 1·052, and in Glasgow 1·3236 ; nitric acid (HNO_3) in London 0·06188, but in Glasgow 0·1705, both these acids being obviously derived from the smoke of coal fires and factories. Near the sea it contains much salt (NaCl), and under circumstances rain may carry down carbonaceous, earthy and mineral, as well as organic matters. The mean total solids in five analyses was 2·24 grains per gallon = 0·032 grams per liter.

Rain collected from roofs is often very impure, from soot, vegetable matter, the excrement of birds, &c., which it washes down.

In England the rainfall varies between 17—35 inches in the south and east and 30—75 in the north and west, but after allowing for loss by evaporation, &c., only a small part is left available for storage. Yet a clear twelve inches per annum over an acre will provide twenty-five gallons daily for thirty persons.

The maximum rainfall must be the basis of all calculations for drainage and the minimum for water supply. The extremes are as a rule 30 per cent. above and below the average.

The rainfall in inches.

× 0·52	=	Gallons per square foot.
× 22620	=	,, ,, acre.
× 3630	=	cubic feet per acre.
× 2323200	=	,, ,, square mile.

Rain water is always highly aerated, the composition of the contained air depending on the relative solubility of the gases, the oxygen amounting to 30 or more per cent. and the carbon dioxide to three or four: or 100 cc. of "air," consist of oxygen, 35 cc. nitrogen, 62 cc., and carbon dioxide, 3 cc. The ammonia is contained chiefly in the first rain that falls. Though thus differing from atmospheric air, it differs still more from that of ground water, which contains far more CO_2 and less oxygen.

When a good and wholesome water is not to be obtained from springs or rivers, as in swampy districts, brackish marshes, &c., and when there is reasonable ground for thinking the ordinary sources to be contaminated by cholera, typhoid or dysentery, it would be highly expedient to fall back on the rainfall for drinking purposes, always bearing in mind the care required in its collection and storage, especially where, as in tropical countries, it is uncertain in amount, and falls at long intervals. The area of the roof must be taken as equal to that of the site, the additional surface due to the slant being disregarded.

Wells and Springs

Ground Water.—The original source of all springs is the rainfall which runs off rocks and impervious soils, following the natural declivities of the surface, and soaks into pervious soils, sinking down until it meets a denser stratum. There is therefore beneath all porous soils, as gravels and chalk, a sheet of water called ground water, which is not stagnant, but following the incline of the impervious stratum flows onwards like a subterranean river, the depth of which varies with the amount of rainfall, rising in wet seasons and falling in dry. Ground water is always more or less aerated, much more so as a rule than that derived from deeper strata. The dissolved "air" varies widely in its composition according to its source. Much of the oxygen and nitrogen and some of the carbon dioxide, is that which was carried down by the

rain as it fell, and calcareous soils may give up more or less CO_2 to the water permeating them, but it is a fact of the highest importance, though not generally known, that by far the greater part is derived from the ground air, with which the ground water is always in contact, and with which it is constantly changing places. The composition of ground air, to which we shall revert when treating of the construction of the basements of houses, differs widely from that of the atmosphere, the CO^2 often amounting to 10, 20, or even 30 per cent., on which account the air of closed vaults and wells has frequently proved fatal to persons respiring it. The source of this carbonic acid, as Wollny has shown by a series of beautiful experiments, is the organic matter in the soil, whence it is evolved, not by a purely chemical process, but by the action of bacteria, in a manner precisely analogous to that of nitrification, by which other organisms convert the nitrogenous organic matter and ammonia compounds into nitrites and nitrates. Thus in soils sodden with sewage or other organic matter, as those near grave-yards, the water of shallow wells is frequently charged with carbon dioxide—aerated, as it is called—in a high degree, even to the extent of sparkling, and presents a most inviting appearance in virtue of its extreme pollution!

Springs.—Should denudation lead to the exposure of the lower stratum on a hill-side or elsewhere, the ground water emerges at the line of outcrop, forming a spring. Other springs arise from the overflow of water contained in the crevices of rocks, and are sometimes intermittent.

Wells are artificial springs formed by digging or boring down to below the level of the underground water, and are divided into surface, deep, and artesian wells (Fig. 24).

Surface Wells may be of any depth, but are so called because they are simply sunk into the ground water, and if shallow they are liable to pollution by the soaking of

cesspits into a porous soil, and from all kinds of filth and organic matter on the surface or in the soil.

Surface wells have been assumed to receive the drainage of a section of the ground, having the form of an inverted cone, the apex of which is at the bottom of the well, and the radius of whose base is twice the depth of the well. But very often, especially where a surface soil of sand or gravel rests on a bed of clay the course of the ground water is quite comparable to that of a river, and pollution may be conveyed *down stream* as it were even for

FIG. 24.

hundreds of yards. Besides containing matters varying in kind and amount with the nature of the soil, and carbonic acid derived from the ground air, they are often highly contaminated with organic pollution. Such wells when in the immediate vicinity of privies, stables, farm-yards, or grave-yards, and anywhere in towns, are always to be viewed with suspicion. The filtration of the water through the soil removes suspended matters, so that it may be clear enough to the eye, but it has little power of removing dissolved impurities.

Indeed some of the city pumps now closed yielded a water shown by analysis to be actually fouler than that of the Thames at London Bridge, and their sparkling appearance was only an indication of active decomposition of organic matters. In a well

in Cripplegate, now closed, Dr. Sedgwick Saunders found in May, 1876: total solids 123 and chlorine 10·4 grams per gallon; ammonia 32·8 and albuminoid ammonia 0·2 parts per million. Several other City wells once held in high repute were in one or other respect as bad or worse.

The relative position with respect to the direction of the flow of the ground water of a well and a source of pollution may affect the purity of the former. If the underground current be from a cesspit to the well it will be dangerous, but not necessarily so in the opposite case of a current from the well to the cesspit. Again, intermittent pollution may occur from a rise in the ground water by which it reaches a cesspit at other times too far above its level to affect it, as shown in the following diagram taken from Galton's *Healthy Dwellings* (Fig. 25). All

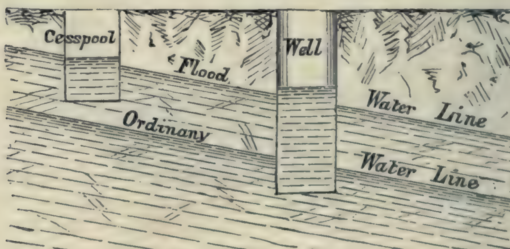


FIG. 25.

wells should be well steined with masonry faced with hydraulic cement, and the parapet raised at least a foot above the ground, which should also be paved for some distance all round to prevent the soiling of the buckets and splashing of dirt by heavy rains.

Deep Wells are those which are sunk through the surface soil, and through an underlying impervious stratum into a deeper water-bearing one. Such waters may be hard and deficient in aeration, but are of great organic purity.

Thus in London there are several attached to the great breweries, which, passing through the gravels and London clay

deep down into the chalk, draw their supplies from the vast accumulation of water overlying the dense beds of greensand and gault beneath the chalk, and originally derived from the rainfall on the chalk hills of Surrey and Hertfordshire, where this formation comes on either side to the surface. The terms "surface" and "deep" as technically applied to wells have no necessary reference to actual depth. A surface well is one dependent for its supply on the superficial beds only, while a deep one draws on the underlying strata. Many a "deep" well does not exceed 20 feet, and one sunk to 200 feet in the chalk at Brighton would still be a "surface" well, though free from the objections attaching to a "shallow" one in a like permeable stratum.

Artesian Wells are deep wells in which the level of the ground water on the surrounding higher lands is such that the water rising in the well overflows at its mouth. They are so called from their occurrence in Artois, but a few such have been sunk elsewhere. The name is, however, though incorrectly, often applied to what we have described as deep wells, when sunk by boring.

Of the rain that falls on any surface a part is evaporated and a part is absorbed, the proportions depending on the character of the soil. Thus loose sands absorb 90 to 96 per cent., chalk 40 per cent., sandstones 20 per cent. to 25 per cent., and stiff clays scarcely any. But the quantity absorbed is influenced by the activity of evaporation, which varies with the degree of humidity of the air. Thus a gravel which in wet weather absorbed 60 per cent. may in hot dry weather absorb but 5 per cent. or even less. Many a shower in summer fails to penetrate, though refreshing vegetation by increasing the humidity of the air, and reducing the loss by evaporation. The water in permeating the soil dissolves out of it various mineral and organic matters, which give to the ground water and springs in each geological system special characters, rendering them more or less agreeable and wholesome or the reverse.

Ground water, properly so called, whence most springs

and wells are fed, being a sheet of slowly moving water beneath the surface, can obviously exist only where a loose soil overlies a dense subsoil, or at least more pervious beds are superposed on less pervious. But in mountainous districts, where granite, gneiss, and trap, or even the harder slates, limestones, and sandstones of the Cambrian, Devonian, and the Silurian systems come to the surface, the rainfall does not soak into the rock, but finding its water between and beneath the stratified beds and into the crevices traversing them, gushes out in copious streams where these beds crop out again on the hill side or mountain steep. The denser the rock the less water is absorbed, but the better catchment surface is presented by it. Such mountain springs and streams furnish generally waters of a high degree of purity, containing not more than from two to six grains per gallon of mineral matters, salts of calcium, magnesium and sodium in the granite, trap and slates, and from four to eight in the millstone grit, &c. The organic matter is in very small amount ; the water may indeed be slightly coloured by peat, but its wholesomeness is not always impaired thereby, though under certain circumstances, soft peaty moorland waters do exert a powerful and dangerous solvent action on lead, probably from the presence of imperfectly known organic acids. Lead poisoning thus produced has of late been alarmingly prevalent in some of the Yorkshire towns.

Springs are rarely met with on the summits or sides of mountain limestone ranges, but the waters, percolating through the numerous fissures in the rock and collecting in subterraneous caverns, appear in copious streams at the bases of the hills. They are clear and sparkling, very free from organic matter, and agreeable to the taste. On the other hand, they are very hard, and their hardness is largely permanent, caused by the presence of calcium, sulphate and in the dolomitic districts of magnesium salts. When the calcium carbonate is in small and

the sulphate in large amount, such waters are called selenitic. Whatever their source they are irremediably hard and unwholesome, inducing dyspepsia, with alternate constipation and diarrhœa.

Magnesian Waters are not desirable. They are said to cause goître; but the true study of this disease is involved in much obscurity. The supply of Sunderland is highly magnesian, that is to say for a potable water.

The alternation of shales and sandstones, and the frequent occurrence of faults in the coal-measures, serve to collect the water often at very moderate depths, and to throw it out at the outcrop in springs, mostly of fair quality.

The water obtained in abundance from the lower beds of the lias clays is of unequal character, but though free from organic impurity when the wells are sunk to great depths, it is often far from wholesome. From 100 to 200 grains of solids per gallon are frequently observed, and Völcker once found 88 grains of calcium sulphate (gypsum), and 41·8 grains magnesium sulphate (Epsom salts); such a water approaching a "mineral" or medicinal one.

In the Oxford clay springs are scarce, and deep sinkings, not always successful, are required to find water. Purgative mineral springs occur in these beds. The waters of the Kimmeridge clays are scanty and bad, being charged with calcium sulphate and iron pyrites (ferrous sulphide). Along the belt of the gault clays skirting the chalk hills of Wilts the villages are wholly dependent on surface waters or rain.

Where the new red sandstone (Triassic) is disintegrated and marly, the waters are like those of other clayey soils, to be found only at considerable depths, and when found are hard from sulphate of lime. But in the sandstone rock it is often of good quality and very abundant.

In the Oolite, owing to the frequent alternation of porous and retentive strata, springs are abundant, at all

depths and elevations, often rising near the summits of hills.

The waters of soft sandstones vary much, being sometime pure and soft, but more frequently the reverse, and not unfrequently possess the character of mineral waters. They often contain 30 to 80 grains of inorganic solids per gallon, consisting of carbonates, sulphates, and chlorides of calcium, sodium, and magnesium, with perhaps iron.

Loose sands and gravels, as the tertiaries overlying the chalk, often supply waters of the utmost purity, but their very porosity, which makes the passage of the ground water through them so easy, renders them, especially near towns, very liable to pollution, if the sand be superficial, and not protected from surface drainage by overlying impervious beds.

Of all springs those most invariably good are met with in the lower chalk, the sheet of water resting on the green sands beneath. Almost or absolutely free from organic matter, yet highly aerated, *i.e.*, sparkling with carbonic acid, they are excellent for drinking. It is true that they are too hard for domestic purposes, involving a great waste of soap, but their hardness, unlike that of the mountain limestone and dolomite waters, is removable by boiling, being almost entirely owing to the presence of calcium carbonate. This high character does not attach to shallow wells, which from the extreme porosity of the chalk and the frequent occurrence of extensive fissures, are very liable to pollution.

All along the line of junction of the London Basin and the chalk at the outcrop of the Tertiary sands (Thanet, Woolwich, &c., beds) copious supplies of pure water are yielded by wells of moderate depth. Such are those of the New River and East London Company in the Lea valley and those at Watford. The water of some deep wells in London agrees at composition with these, and is quite different from those in Brighton and the wells of the Kent Company round Blackheath, &c., whence one may assume that though sunk into the chalk, they derive their supply from the overlying sands.

The bed of impervious gault and lower greensand beneath the chalk is not continuous, and where it is wanting, as at Kentish Town and Richmond, little or no water is obtained at any depth. So far as present experience has gone, it is then useless to bore into the sandstones beneath.

Surface wells collecting the waters running off stiff clays, or sinking for a short distance into alluvial, cultivated, and other organically polluted soils, are always dangerous.

Wells surrounded by farm-yards, &c., are inevitably contaminated, and those in towns are equally so. For example, the wells within the city of York show greater pollution than the river Ouse, and C. Schmidt found at Dorpat the total solids of the wells inside the town 1·166 grams per liter, and of those outside 0·448 grams.

Marsh Waters vary as regards their salts, but contain much vegetable matter, 10 to 40 grains per gallon. They should never be drunk without boiling at least if not without other precautions or modes of rough purification.

Wells near the sea are often brackish from the entrance of salt water. When the water in such wells is at all useable, it must be derived from a stream of ground water flowing seawards, since no filtration can remove dissolved salts, or render such water fresh. On low-lying shores not traversed by rivers, it may be quite impossible to obtain fresh water, whereas when lofty hills skirt the shore, or run parallel with it, even at a distance of many miles, it may be had freely by boring, even within a few yards of the sea.

This contrast is well shown on different parts of the Australian coasts; and strange as it may seem, fresh water may, under certain geological conditions, be obtained in like manner by boring beneath the sea bottom, as at the forts in the Spithead, which are provided with water from deep wells sunk into the chalk, precisely like those in the London basin.

Along the range of the South Downs, the rainfall over the heavy clays of the Weald, in excess of that which goes to feed

rivers, finds its way through fissures in the chalk hills to the sea, gushing out in places between high and low tide marks. Such abundant supplies of water running to waste without irrigating the land probably exist elsewhere, but as yet Brighton alone has fully utilised it, though the source seems so inexhaustible that it might be drawn on for the metropolis as well.[1]

Where the physical features of the shore are not such as to maintain a strong current seawards, the movements of the ground-water may be influenced by the rise and fall of the tide, and the same may be noticed in the neighbourhood of tidal rivers. The characters of the water may or may not be affected thereby.

There is a danger of pollution to which wells, however deep sunk in hard but porous formations, as oolite and chalk, are exposed, arising from the fact that in such rocky soils both wells and cesspools are often constructed with imperfect masonry or with none whatever.

Rivers, originating mostly in hillside-springs, are fed by the drainage of porous soils, by the rainfall following the declivities of the land and by springs rising in their beds. River water, where not polluted by the sewage of towns, is more uniform in its composition than spring waters, containing more organic and less dissolved inorganic matters than good average springs, but also a variable amount of suspended matters, organic and inorganic, removable by settling and filtration. These suspended matters are most abundant when rivers are swollen by heavy rains, rendering them perhaps visibly turbid and muddy, though freer from dissolved impurities than when apparently clearest. It is during drought that the dissolved, indeed the total, impurity is at its height.

But when the volume of water is great, the current not so rapid as to lift earthy particles, and sewage can be excluded, rivers may furnish potable waters of unex-

[1] See my paper on "The Water Supply of Inland and of Maritime Towns," read in the Engineering Section at the Seventh International Congress of Hygiene.

ceptionable character. The water supply of Paris, so far as derived from the Vanne and the Dhuys, surpasses that of London in purity. The "yellow" Tiber is in rainy weather turbid with clay mud, but its tributaries are remarkably pure.

But the fact that a river has been at some point in its course contaminated by sewage, does not disqualify it throughout as a source of water for drinking and domestic use. Rivers as they flow, besides being diluted by affluents, springs, and surface drainage, undergo a self-purifying process, from the action of atmospheric oxygen, vegetation, &c., such that at some point lower down—the distance depending on the volume and rapidity of the stream, the nature of its bed, and the temperature—the water becomes again as pure as it was before the entrance of the pollution. Thus there is no more organic matter in the Thames at Hampton Court than at Lechlade in Gloucestershire, 116 miles higher up, though it has received the sewage of numerous towns between those places.

But the most striking illustration is to be found in the Seine, as described by the commissioners appointed to report thereon in 1875–76. The sewers of Paris discharged into that river (which above the city presented the ordinary appearance of others of its size) black fœtid greasy streams, the solid particles from which were deposited as shoals or as black and grey mud on its banks. This mud was the seat of active fermentation, giving off countless bubbles of gas, some of which in hot weather attained enormous size, carrying with them the black mud to the surface, and neither fish nor plants could exist in its waters. Gradually the appearance of the river improved; between Epinay and Argenteuil it was still dark, but the mud had subsided and fish reappeared. Below Bezons the vegetation on the banks was luxuriant, and water plants grew in such profusion as to impede the flow. At Meulan and Vernon all pollution had disappeared, and the water was purer than it was above Paris. The free oxygen dissolved in river waters, and the organic matters capable of undergoing putrefaction, are generally present in inverse proportions, since the former is removed in the oxidation of the latter. Thus, the total nitrogen in organic combina-

tion and in ammonia, which is a product of the decomposition of such matter, was in grams per cubic metre at the Bridge of Asnières above Paris 1·5 ; at Clichy and at St. Denis, below two of the great intercepting sewers of the city, 4·0 and 7·0 respectively ; but at Meulan and Vernon, below Paris, 2·2 and 1·4. Again the dissolved oxygen at Asnières was 5·34ccs. per liter, at Clichy 4·60, at St. Denis it had been reduced to 1·02, while at Meulan and Vernon it had risen again to 8·17 and 10·40. Thus at Vernon the organic matter was less and the free oxygen nearly twice as great as at Asnières before the sewage of the capital had been admitted. The enormous proportion of oxygen at Vernon is in great part due to the active vegetation. The analysis of the Rhine water at Bonn, on the other hand, affords a striking illustration of the self purification of a large and rapid river after having received in its course the sewage of countless towns, but also purer streams from the hills.

The process of purification is, we believe, less of a purely chemical character than is generally supposed, and mainly due to the action of animal and vegetable life of every grade, which is aided, and in some cases initiated or rendered possible, by the dilution with purer water received from affluent streams, and from springs in the bed of the river itself. The volume of the Thames at Hampton Court is vastly greater than it was at Lechlade. It should also be mentioned that between Paris and Meulan the Seine receives a large addition of purer water by the junction of the Oise ; the area of the basin and the mean summer discharge of the latter being to that of the former as 2 to 5.

Any water, which, if kept long in a warm place, undergoes fermentive or putrid changes, and gives off an offensive or faint smell, is unfit for use, though when fresh it might have been devoid of colour, taste, or smell. Such are the effluents of sewage farms, though they may not render the water of the rivers into which they are discharged unfit for drinking at a point some distance lower down, their organic constituents being rapidly oxidised or converted into ammonia salts. Tainted waters thus purify themselves, their organic constituents being resolved into ammonia, nitrates and nitrites, carbonic acid, chlorides, &c., a fact well known to sailors before the use of condensed vapour of sea water was introduced.

Water Analysis

Before treating, so far as the limits of this work permit, of the methods of water analysis, we must make a few remarks on the importance, from a sanitary point of view, attaching to a few of the chief impurities, though insisting on the fact that the chemical composition alone is no real evidence of its wholesomeness, since analyses can only show the quantity and not the nature or condition of the organic matter, and that only at a given moment.

Chlorides in large amounts should raise suspicion when there is also much organic impurity, *i.e.*, ammonia, nitrates and nitrites, phosphoric acid, and, if the fouling be recent, oxidisable organic matter, for the source of the chlorides is urine. When there is, on the other hand, little or no evidence of such pollution, the salt is derived from springs, or from the sea ; and it is probably attended in the one case by sodium and calcium carbonates and sulphates, in the other by magnesia ; it is also generally in large amount.

Ammonia, without nitrates and nitrites or chlorine, indicates vegetable contamination ; with them, probably animal. Changes in the relative proportion of nitrates and nitrites are owing to the presence of bacteria, some exerting a reducing action, and others the opposite, according to circumstances.

Various expedients have been devised for estimating organic matter, such as its reaction with potassic permanganate, which it reduces, being itself oxidised thereby. This is seen in its simplest form by the decoloration of a few drops of Condy's fluid, and has been elaborated into a quantitative process. Drs. Frankland and Armstrong applied the ordinary procedure of ultimate organic analysis to the dried residue, estimating thereby the carbon and nitrogen contained in the organic matter, but the process demands great skill, and is, moreover, too tedious for general use. Messrs. Wanklyn and Chapman invented a process now widely employed, which consists in first

estimating the ammonia existing free or combined, or, as they call it, saline, and next by distilling the water with a strongly alkaline solution of potassium permanganate, converting a more or less definite proportion of the organic matter into ammonia, which they call albuminoid. The more recent the pollution, the larger the proportion of albuminoid to free and saline ammonia. But another application of permanganate for determining the oxygen required for the complete oxidation of all oxidisable matters, *i.e.*, approximately the organic matter present, is a most important procedure.

Dr. Frankland maintains that nitrates indicate previous in the sense of remote contamination, but Dr. Ashby and Mr. Hehner have shown that such pollution may be very recent when bacterial agency is active. The more advanced the putrefaction of the organic matter, the more easily is it oxidised, and some think the more injurious, but living organisms will be the most refractory, and may yield but a very small amount of nitrogen or ammonia: a mere trace of albuminoid ammonia derived from enteric or cholera stools teeming with bacteria may be more dangerous than a hundred times the weight of other animal or vegetable matter.

The bacteriological examination of a water is far more valuable than the chemical and should never be omitted. Gelatin cultures are made from fresh samples, and the number of colonies, *i.e.*, of living bacteria in a c.c. calculated, since they give an indication of its purity. They should never exceed 50 to 100 in the c.c. It is very rarely that specific organisms can be identified, but the presence of the B. coli, easily recognised in stained preparations, affords positive proof of fæcal contamination, and therefore of the possibility of typhoid bacilli, and several outbreaks of typhoid fever have thus been indisputably traced to water supplies that analysts had pronounced pure.

A simple microscopical examination will, however, detect animal and vegetable tissues, as spiral vessels, muscular and elastic fibres, epithelium cells, and minute organisms, and the probable source of the pollution.

Impurities are either suspended or dissolved; and inorganic, animal or vegetable, and living organisms may be present.

The colour and degree of turbidity are best seen through a column of water two feet deep, in a clear white glass vessel standing on a slab of white porcelain. Perfectly

pure water has a bluish tint, and permits of the bottom of the vessel being distinctly seen, even at a depth of several feet. Turbidity, usually described as very slight, slight, turbid, and very turbid (VST, ST, T, and VT), obscures it, and a blue green, green, yellow green, yellow, yellow brown, or brown hue, similarly described by initial letters, indicates less or more organic pollution.

Some chemists mark the depth of each tint by adding the numerals 0, 1, 2, and 3, and Messrs. Crookes and Odling employ two wedge-shaped hollow glass vessels filled, one with a brown and the other with a blue solution, and made to slide across one another in front of a circular aperture in a sheet of metal, by which means any desired combination of brown and blue can be obtained. Each prism is graduated along its length from 1 to 50, these figures indicating the thickness of the solution at that particular point in millimeters.

The water is poured into a two-foot tube fixed horizontally on a stand just below the combined prism, and having in front of it a plate with a similar circular aperture, and the apparatus is placed before a well-lighted window. The observer, standing a short distance off, compares the two disks of light presented by the apertures, and adjusts the prisms until the colours of the two exactly correspond. A metal pointer over the centre of that in front of the prisms indicates the thickness of each, which is stated thus—20:25, meaning that the colour of the water is the same as that produced by the superposition of a layer of the brown solution, 20 mm. thick over one of blue of 25 mm.[1]

Suspended clay, &c., give a yellowish, chalk a whitish, sewage a light brown, and vegetable matters a darker hue, but these are not absolutely distinctive. Inorganic matters are mostly deposited after boiling, organic less completely, unless in the presence of chalk. The smell

[1] The brown solution is made by dissolving ferric chloride and cobalt chloride in distilled water in such proportions that a liter of the solution contains 0·7 grams of metallic iron, and 0·3 grams of metallic cobalt, a little free hydric chloride being present. The blue solution consists of 5 grams of pure crystalline cupric sulphate in a liter of distilled water.

of sewage may generally be best perceived at the commencement of boiling.

To examine the sediment microscopically, the water should be allowed to stand in a conical glass for some hours, and the clear fluid decanted off by a siphon. Particles of sand are angular, those of clay, round and smooth; both are unaffected by acids which dissolve chalk. Vegetable *débris*, wood, tissue of leaves, spiral vessels, starch globules, &c., are easily recognised, as are muscular fibre, hairs, epithelium, and other animal tissues. Sewage matters present the appearance of globular masses of a reddish-brown or ochreous hue.

Living organisms of all kinds, animal and vegetable, are frequently met with. They indicate, of course, the presence of pabulum, mostly of an organic nature, but do not of themselves suffice to condemn a water. Bacteria, bacilli and vibriones (minute jointed rods), and micrococci (spherical bodies, single, grouped or in chains), require organic carbonaceous matter, nitrates, a trace of phosphates, and oxygen; others, however, flourish best where oxygen is deficient. No water is free from them, but their number affords an approximate estimate of its impurity. And while some are connected with the ordinary processes of decomposition, others—we cannot always distinguish which—may be the germs of specific diseases. It is rarely if ever possible to verify the presence of the bacillus of typhoid, but the B. coli grows freely in nutrient gelatin at a moderate temperature, and though almost ubiquitous, is, if in any numbers, proof positive of fœcal contamination.

The growth of the *B. coli* is so much more vigorous that if present in large numbers it is apt to crowd out the feebler *B. typh.*, whence the fouler the water the sooner is the latter lost.

Low vegetable organisms found in water may be divided into (1) algæ and diatoms, and (2) fungi. The former are present in nearly all running streams, and

therefore cannot be held to contra-indicate its use; indeed, they may assist in purifying and oxidising it. Fungi, on the other hand, requiring the presence of nitrogenous, carbonaceous, and phosphatic matter, are evidence of impurity. The so-called sewage fungus of Heisch forms rapidly in water, to which sugar has been added if kept in a warm place. It is therefore not characteristic of sewage, but indicates an amount of decomposing organic matter enough to absolutely condemn any water. It presents the appearance of grape-like clusters of spherical transparent bodies, and in its growth it develops butyric acid, recognisable by its rancid odour. The spores are derived from the air.

The distinctly animal Rhizopods and Infusoria are abundant in ponds, tanks, and some river waters; harmless in themselves, they prove the presence of organic matter, and some, as Paramœcia, seem to point to serious degrees of pollution.

The higher forms of hydrozoa, rotifers, and entomostraca occur so frequently, especially in spring time, in running brooks, that little weight can be attached to their presence. Anguillulæ, on the other hand, require so much organic impurity for their nourishment that they must be looked on with great suspicion; while leeches and the eggs or embryos of filaria, ascarides, flukes, and the various species of scolecida, and other entozoa, are of the highest importance in themselves. Most entomostraca, as Mr. Sorby has shown, subsist on the undigested particles in fæcal matters, and thus indicate the presence of sewage. Leeches have been known to cause dangerous hæmorrhages from the fauces and stomach; and in the tropics the guinea worm, Bilharzia, &c., enter the human body from the water of tanks and like polluted sources.

Water may be impure from the first, being derived from a polluted source, as a river receiving sewage or a surface well, or it may be rendered so by the en-

trance of sewage, &c., into a well in itself clean or into a reservoir.

Dr. Garrett, of Cheltenham, has recently called attention to the fact that waters originally perfectly pure, but containing much lime may, when stored in open reservoirs exposed to the light, become undrinkable, acquiring "fishy," sulphurous, and other offensive odours and tastes, from the growth and decay of the *Chara*, a plant encrusted with calcareous granules embedded in a gelatinous matrix which dies down in the autumn and becomes disintegrated, when the *débris* is found to swarm with animal and fungoid organisms of every kind, including *Lyngbya*, *Beggiatoa*, *Nostoc*, and other algæ, by which the offensive matters are formed. The *Chara*, however, like other green plants will not grow in a covered reservoir, light being necessary for the formation of chlorophyll.

Water may be stored in cisterns in which filth is allowed to accumulate, as is often the case in towns, especially in the poorer quarters; and even filters, as we shall show, may contaminate the water as it passes through them. Metallic impurities may be derived from the material of pipes or cisterns, or the vessels used for the carriage of water may render it foul and unwholesome.

A knowledge of the normal constitution of the waters of a locality, dependent on the geological formation, is indispensable for the correct interpretation of the results of chemical examination, unless it afford positive evidence of pollution. Nor is any report complete or satisfactory without a bacteriological examination. The details of this procedure are too technical for consideration here, suffice it to say, that while on the one hand the mere number of bacteria, most of them innocent, though of course bearing a certain relation to the purity of the water, is of little value in itself, save as an indication of the efficiency of filtration, one only, the *B. coli*, being conclusive evidence of fæcal contamination. Lastly, every report should include an investigation of the surroundings of the source, and the possibility of pollution, since no examination of the water itself can go beyond its actual condition, or give assurance of the present purity being maintained.

The following analyses may be taken as fair samples of potable waters from various sources.

	Rain-water from roof, Univ. Coll., London.	Upland Surface Waters			Spring Waters	
		Lake Bala, Wales.	Peaty Moorland, Scotland.	Source of Irwell, Lancs.	Mountain	Rock, red Sandste.
					Acqua Marcia, Rome.	Guy's Cliff.
Total Solids . .	2·0	1·95	7·50	4·50	20·73	35·00
Hardness . . .	0·50	0·28	3·50	4·60(?)	19·25	?
Chlorine	0·15	0·706	0·50	1·05	2·75	3·08
Nitrates (HNO^{3})	0·01	None	0·01	0·03	0·01134	0·21
Nitrites	None	None	None	None	None	None
Ammonia . . .	0·0005	0·0007	0·0015	0·016	Organic C; 0·0098	0·004
Album. Am. . .	0·0005	0·0010	0·0185	0·013	N; 0·0021	0·007
Ox. absorbed in 2 hrs. at 80°C.	0·005	?	0·150	?	0·0024	0·031
Authority . .	Kenwood	Wanklyn	Kenwood	Davis	Cannizzaro	Stokes

	Metropolitan Water Companies.					R. Kennet, Thatcham (unfiltered).
	West Middlesex.	Lambeth.	East London.	New River.	Kent Co.	
	Thames (filtered).		River Lea (filtered).	Chalk Wells.	Chalk Wells.	
Total Solids . .	18·55	19·95	23·00	22·00	27·00	24·50
Hardness . . .	12·95	14·2	15·00	16·00	19·00	?
Chlorine	1·26	1·33	1·50	1·30	1·50	1·12
Nitrates (HNO^{3})	0·133	0·147	0·16	0·16	0·32	0·339
Nitrites	None	None	None	None	None	None
Ammonia . . .	None	None	0·0010	0·0005	0·0005	0·0014
Album. Am. . .	0·0056	0·0056	0·0040	0·0025	0·0020	0·0112
Ox. absorbed in 2 hrs. at 80°C.	0·042	0·0434	0·028	0.015	0·0120	0·074
Authority . .	Kenwood	Kenwood	From Official Analyses.			Stokes

	Deep Wells			Surface Wells		
	Silurian	Oolite	Chalk.	Present Pollution.	Remote Pollution.	Good Water, near sea, Yarmouth, I. of Wight.
	Anglesea.	Elton, nr. Peterborough.	Debden, Saffron Walden.			
Total Solids . .	17·00	70·00	44·10	35·50	32·00	50·40
Hardness . . .	?	?	?	20·50	19·50	27·00
Chlorine	8·54	2·38	5·83	6·50	6·50	10·08
Nitrates (HNO^{3})	0·07	None	1·13	0·70	1·70	0·108
Nitrites	Traces	None	Traces	None	Traces	None
Ammonia . . .	0·004	None	0·0084	0·015	0·002	0·0014
Album. Am. . .	0·011	0·007	0·0042	0·018	0·003	0·0070
Ox. absorbed in 2 hrs. at 80°C.	0·07	0·031	0·030	0·150	0·038	0·0250
Authority . .	Stokes	Stokes	Stokes	Kenwood	Kenwood	Stokes

The public water supply of London may be taken as a standard of highly satisfactory purity; derived in great part from a large but sluggish river, draining a low, densely-peopled and highly-cultivated country, receiving the sewage crude or purified (?) of about a million persons, and submitted to simple sand filtration, it shows what may be reasonably expected of all water supplies intended for public use. Though a purer source is much to be desired, it will, from a chemical standpoint, compare favourably with a large, perhaps the greater, number of country wells, its danger being rather in its surroundings and the possibilities of specific contamination by the germs of enteric fever or cholera.

The London waters vary among themselves, and at different times, but the general results of the examinations made every eighth day by Messrs. Crookes and Odling gave

Hardness (Clark's Scale) ...	12° to 18	in grains per gallon.
Ammonia	0?	
Chlorine	1·2 to 1·5	
Nitrogen (= Nitric Acid) ...	0·15 to 0·2 (= 0·7 to 0·98)	
Organic Nitrogen	0·01 to 0·035	
,, Carbon	0·05 to 0·2	
Oxygen absorbed by organic matter (in the cold for 3 hours)	0·01 to 0·09	

N.B.—The alleged entire absence of ammonia to the third decimal place, when the presence of impurity is evident, is not in agreement with the results obtained by other chemists, and can be explained only by the mode of analysis followed by these gentlemen. *Quantum valeat.*

Messrs. Crookes and Odling's analyses were carried out on behalf of the companies drawing their supplies wholly or in part from the rivers Thames and Lea, and do not include the waters of the Kent Company, derived exclusively from deep wells in the chalk.

The following considerations and directions for water analysis are abridged from my *Health Officer's Pocket Book*, second edition.

Water Analysis.

Indications of high value.	Indications of secondary value.
Suspended solids.	Fixed or volatile, *i.e.* inorganic and organic.
Dissolved solids.	Loss on ignition.
Total, temporary and permanent hardness.	Alkalinity (in terms of H^2SO^4 neutralized).
Chlorine.	Nitrites.
Nitrates (as HNO^3).	Sulphates (as H^2SO^4).
Ammonia.	Any metals, as iron, &c., in solution.
Albuminoid ammonia.	
Oxygen absorbed.	

The practice of stating results in grains per gallon (*i.e.*, parts per 70,000) presents no advantages, is unscientific, and renders comparisons with other and foreign analyses difficult. It is much to be desired that all analyses were stated in parts per million, *i.e.* in milligrams per litre, or in parts per 100,000, as preferred, involving merely the position of the decimal point.

The statements are, however, easily convertible by a simple multiplication. Thus—

(1) Grains per gallon × 14·3 = parts per million or milligr. per litre, or × 1·43 = parts per 100,000.

(2) Parts per million × 0·07 = grains per gallon, or × 0·7, or × $\frac{7}{10}$ = pts. per 100,000.

(1) The former operation will be rendered easier by the help of the following table, which may soon be learned by heart.

1	143	4	572	7	1001
2	286	5	715	8	1144
3	429	6	858	9	1287

(2) The latter requires merely the multiplication table of 7, and regard to the decimal places to be added to the product.

Chemical Indications.

Total Solids have no necessary significance as regards pollution, depending to a great extent on the solubility of the rocks through or over which the water flows; they are lowest in upland surface waters, and highest in those from deep wells. The suspended solids are always increased during floods. See analyses of the Irwell on p. 355.

Chlorine.—The absolute quantity teaches little. The local standard or the Cl. present in waters known to be unpolluted should be learnt, when a marked excess over this, with a corresponding excess of ammonia, affords a presumption of sewage pollution which should be verified by inspection of the surroundings. The

chalk beneath the London clay is highly saline, and some deep waters in the coal measures contain 50 parts per 100,000, though beyond reach of pollution.

Free Ammonia is, as a rule, in direct proportion to organic pollution, and is accompanied by albuminoid ammonia and chlorides. In upland surface waters it ranges from *nil* to 0·002 parts per 100,000, or after floods to 0.004. And in well-waters should not exceed 0·005.

But it may be present alone, without organic pollution, in deep wells and springs, from the reduction of nitrates by the action of iron.

Organic (*albuminoid*) *ammonia*, the immediate product of organic matter, should not exceed 0·003 to 0·005 pts. per 100,000 in wells, though in upland surface waters 0·008 to 0·01, if unaccompanied by an excess of Cl., may be present from the decay of vegetable matter. But if combined with much Cl., or more than 0·005 of free ammonia, or ·5 of N as nitrates, it is positive evidence of sewage or manure.

Nitrates and Nitrites were described by Frankland as indicating "Previous sewage contamination; but the expression is misleading, for nitrates, being the ultimate product of the "mineralisation" of organic matter, are evidence of self-purification, and are in themselves harmless. The organic matter may, indeed, be of geological age, as in deep chalk waters, while nitrates may be entirely absent from crude sewage. In upland surface waters any appreciable amount indicates the presence of manure, and if as much as ·03 per 100,000 be found the water should be well filtered; but in well waters ·4 or ·5, if unaccompanied by organic ammonia or other evidence of sewage need not be deemed a defect.

Nitrites may be formed in the reduction of nitrates, referred to under free ammonia, but under ordinary circumstances they are considered, as being the earlier and transitional stage in the nitrification of organic matter, to indicate the recent or present character of the pollution.

The oxygen absorbed is a measure of the oxidisable matters, most, though not all, of which are organic, and these usually of animal origin. It is a valuable, though not unerring indication, specially applicable to estimating the local pollution and self-purification of a river at successive points in its course. See on the Seine, pp. 279—280.

Temporary hardness, unless extreme, is no objection to a potable water, but any marked amount of earthy salts involves the crusting of pipes and boilers, and a great waste of soap. It is stated in degrees, by which were originally meant grains of

$CaCO^3$ or its equivalents in a gallon. All other nations express it in parts per 100000, but in Germany these are calculated as CaO instead of $CaCO^3$. Thus, 70° English = 100° French, &c. = 56° German.

Permanent hardness in natural waters, as those of the lias and dolomite, is caused by the presence of sulphates, chlorides, &c., or any of the alkalies and alkaline earths. So called "mineral" waters belong to this class, rich in sulphates and chlorides of sodium, magnesium, &c.

In rivers, however, permanent hardness, with alkalinity or acidity, indicates pollution with factory waste.

Lead may in some few localities be derived from veins of galena, but elsewhere it is the result of the action on the lead pipes and perhaps cisterns in houses of organic acids formed in peat and some tertiary sands. This occurs with soft waters only, for hard waters soon coat the lead with an insoluble deposit.

Chemical Procedures.

The solids, total, suspended or dissolved, are ascertained in the usual manner.

Hardness—total, temporary and permanent. For the total, the standard soap solution is cautiously buretted into a 6-oz. bottle containing 50 c.c. of ordinary waters, or 25 or 10 diluted to 50 of very hard ones, which is well shaken after each diminishing addition until the lather becomes permanent, when the hardness corresponding to the number of c.c.'s and tenth of c.c.'s of soap solution used is read off from a table. The permanent hardness is obtained in like manner from a sample that has boiled for 15 or 20 minutes, and the temporary by deducting it from the total.

Chlorine. A standard solution of $AgNO^3$ is very cautiously buretted in 100 c.c. of the water in a porcelain dish, to which a pale yellow colour has been given by pot. chrom., and well stirred meanwhile. So soon as a red colour appears and persists, the c.c. of silver solution used are read, each c.c. representing 1 part in 100000 of Cl.

Ammonia. Free and *organic* or *albuminoid.* From 500 c.c. of the water in a retort with condenser, &c., two samples of 100 c.c.'s are distilled over into two Nessler tubes, and into a third if the second react with Nessler's test. Then after adding to the residue of ammonia-free water in the retort 50 c.c. of alkaline permang. solution, two more Nessler tubes are filled with the distillate, to 100 c.c. and 50 c.c.

Practically all the free ammonia goes over with the first 200 c.c., but what remains though negligible must be entirely driven off, that it may not be reckoned with the organic.

The ammonia in each of the four tubes is estimated in the same way, and the results of the first pair added for the free, and of the latter pair for the organic ammonia. The tube and a similar one with pure distilled water standing on a white slab, 2 c.c. of Nessler's test added to each, and to the pure water so much of the standard ammonia solution as will probably give the same tint of brown with Nessler. If either be darker some must be decanted off, and when exactly matched the relative depths noted for correction. Each c.c. of the standard ammonia solution represents with 2 c.c. of Nessler in 100 c.c. of water, ·002 mg. in the 100 c.c. tube = ·02 mg. per liter or 2 parts of ammonia in 100,000. Correction for excess or deficiency in the ccs. of standard ammonia solution used, necessitating a reduced depth in either tube, are made by simple proportion, *e.g.*, since 5 ccs. giving the same shade in 100 cc. of the distillate and of the control tube indicate ·05 mg. in the former, it will, if 20 cc. have to be withdrawn from the latter, give ·04 mg., and if from the former ·0625 mg. in the distillate.

N. as nitrates.—Evaporate to dryness in two beakers 100 cc. of the water, and of the standard KNO^3 solution, when cool drop into each 1 cc. of phenol sulphuric acid, replace on the water bath for 10 minutes, then wash out each repeatedly to 50 or 60 cc. in Nessler tubes, add 25 cc.of KHO solution to each and fill up with distilled water to 100 cc. Compare the colour of the potass picrate formed by the action of the reagents and drawing off from the darker till the shades correspond, calculate as in Nesslerizing from their depths, each cc. of the standard KNO^3 solution representing 1 part of N as nitrates in 100,000.

Nitrites.—A qualitative test is considered sufficient. To 25 cc. of the water in a test tube add 5 drops of the KI solution and 5 of the starch solution, mix well and add 10 cc. of dilute H^2SO^4, when if any appreciable amount of nitrites be present a blue colour will appear.

Griess's Test for Nitrites is capable of being made quantitative.

Test.—To 100 ccs. of the water in a glass cylinder add first 1 cc. of the sulphuric acid, and then 1 cc. of the metaphenylene diamine solution. If the red colour appear at once, repeat with a diluted sample, so that the reaction shall not occur until after a few minutes. Two similar cylinders, one containing the water under examination, diluted if necessary, and the other pure distilled water, add equal quantities of the test solutions, and to the latter the standard solution drop by drop from a burette, comparing the colours in each exactly as in Nesslerizing. But since the colour rapidly deepens the observations must be begun and made simultaneously.

Oxygen absorbed.—At present the Soc. Pub. Anal. allow for the operation four hours at 80° F., though 80° C. would be better.

Taking two 12-oz. stoppered bottles, pour into one (A) 250 ccs. of the water to be examined, and into the other (B) the same of freshly boiled Aq. dest.; to each add 10 cc. of dilute H^2SO^4 and 10 cc. of sol. pot. permang., then let them stand at the temperature, and for the time decided on, but adding the permang. solution, 10 cc. at a time to A so often as the colour fades. At the end of the time add to each 2 cc. of KI solution, turning the pink to yellow, run in from burette thiosulphate solution, till it becomes a faint straw colour, next 1 cc. of starch solution giving a deep blue, and lastly run in more thiosulphate slowly till the blue disappears. Note the number of ccs. of thiosulphate solution required by each, that by B corresponding to 10 cc. of the pot. perm. sol., *i.e.* 1 mg. of oxygen; call this x and that by A call y; the quantity of oxygen consumed by the oxidisable matter in A will be $1 - \frac{y}{x}$ mg., or if a second or third 10 cc. of pot. perm. sol. were needed $2 - \frac{y}{x}$ or $3 - \frac{y}{x}$ mg. and since 250 cc. only of the water were used this result × 4 gives mg. in 1000 ccs. or parts per 100,000.

For the various standard solutions and reagents see Appendix.

Tests for Impurities in Water

Those who are unable to carry out a complete analysis, may use simple and merely qualitative tests not involving distillation, but capable of indicating serious degrees of pollution.

Lime is indicated by a white precipitate with oxalate of ammonia: six grains per gallon, a slight turbidity only; sixteen a considerable precipitate.

Chlorides give, with silver nitrate and dilute nitric acid, a white precipitate soluble in ammonia. One grain of chlorine per gallon gives a slight haze, four or five a marked turbidity, and ten grains a considerable precipitate.

Sulphates.—Barium chloride with dilute hydrochloric acid enough to give a strong acid reaction, throws down a heavy white precipitate if the sulphates be in considerable amount. Three grains of hydric sulphate per gallon give an immediate haze, and after a time a slight precipitate. 1½ grains do not till later.

Nitrates.—The most delicate test is a solution of brucine (1 gram in 1000 ccs. of distilled water) and pure sulphuric acid. The water and brucine solution in equal quantities are mixed in

a test tube, and the strong sulphuric acid poured gently down the side so as to form a layer beneath the water and brucine. Half a grain of nitric acid per gallon gives a marked pink and yellow zone.

Or if the water be evaporated to dryness in a white porcelain basin, and a drop of pure sulphuric acid and a crystal of brucine dropped on to the residue, ·01 grain per gall. can easily be detected.

Or add to the water an equal bulk of pure sulphuric acid, and after it has cooled, pour on a solution of pure ferrous sulphate, so that it may float on the dilute acid; after a variable time an olive-coloured zone will be seen at the plane of contact.

Or add to the water and sulphuric acid prepared as for the brucine test a drop or two of a 2½ per cent. solution of pyrogallic acid slightly acidulated with sulphuric acid when, if nitrates be present, a zone of pink turning purple will appear.

Nitrites.—Nitrous acid decomposes potassium iodide, and free iodine gives a blue colour with starch. To apply this test boil twenty parts by weight of starch with 500 of water; filter when cold and add one part of potassium iodide. If this solution be mixed with the water to be examined, and dilute sulphuric acid added, the blue colouration will appear immediately should nitrites be present.

Ammonia is detected by Nessler's solution of mercuric iodide in potassium iodide, which gives a brown colour or precipitate, according to the quantity of ammonia present. If this be small the colour should be observed through a column of several inches of water over a white ground. This test may be made quantitative by comparing the tint with that produced by the same quantity of the test solution in one of ammonia of known strength, obtained by adding an ammonium salt to distilled water and test solution until the same hue is obtained.

Oxidisable Organic Matter in the absence of nitrites is indicated by the decolouration of a few drops of a solution of permanganate of potash, or a still more delicate test is gold chloride in a perfectly neutral or slightly acid water, which, after boiling for twenty minutes, gives a colour varying from rose pink to violet or olive, or a dark violet to a black precipitate, according to the amount of oxidisable matters present. In this case, too, nitrites must be absent.

It is only thus that the presence of crude organic matter can be demonstrated without the appliances for converting it into (organic) ammonia, and distilling it over, after all the ammonia already existing as such, free or combined, has been removed by the same means. But there are some other oxidisable matters not, like the nitrites, of organic origin, which react in like manner.

Iron.—Ferrocyanide of potassium (yellow prussiate) gives a blue with ferric salts, and ferricyanide (red prussiate) with ferrous, the liquid being acidulated with dilute HCl.

Lead.—Place some of the water in a white porcelain dish, and stir it with a glass rod dipped in ammonium sulphide ; wait till a black colour is produced, then add a drop or two of hydrochloric acid. If it do not disappear it is due to lead.

There are some tests which are best applied to water, concentrated to one-twentieth part of its original volume.

Phosphoric Acid.—Add nitric acid, stir with a glass rod, then add molybdate of ammonium, and boil. A yellow colour, and on standing a precipitate, indicates phosphates.

Magnesia.—Add ammonium oxalate to throw down lime ; filter, then add some drops of solutions of sodium phosphate, ammonium chloride, and ammonia. A crystalline precipitate of triple phosphate appears within twenty-four hours.

Other impurities, as arsenic, copper, and zinc, are of less frequent occurrence, but may be detected in concentrated waters by the tests given in books of chemical analysis.

Effects of Impure Water

These may be sudden and marked, but far more often are insidious, showing themselves in the general deterioration of the health. The most dangerous impurities are choleraic, dysenteric, and typhoid stools ; next come ordinary fæcal and other animal matters ; and it would appear that specific poisons act more virulently when added to a polluted than to a pure water.

There is no evidence that dissolved sodium chloride of inorganic origin, or sodium and calcium carbonates in small quantities have any injurious effects. It is otherwise with chlorides, sulphates, and nitrates of calcium and magnesium, especially with some individuals. These are apt to induce various forms of gastro-intestinal catarrh, manifested by dyspepsia and constipation or diarrhœa, according to circumstances.

Diarrhœa and other gastro-intestinal derangements are caused by suspended mineral matters acting as mechanical irritants, by suspended vegetable and still more by

suspended animal matters, and by dissolved animal impurities, though these act more usually by inducing a low state of the general health. Sewer gases dissolved in water cause diarrhœa, sore throats, boils, and a general sense of malaise, or under certain circumstances may communicate enteric fever, diphtheria, &c.

The relation of enteric fever, diphtheria, dysentery, and cholera to water will be considered in the part devoted to these diseases.

Goitre.—There is overwhelming evidence that certain waters have the property of producing this disease, in some cases with almost incredible certainty and rapidity, and also that the great majority of such waters are derived from magnesian limestone rocks. But it is asserted by several observers that these rocks are absent in some places where goitre is endemic, especially by Dr. St. Lager, who argued that the presence of metallic sulphides, as iron pyrites, is an important factor. More remarkable is the absence of goitre at Sunderland, where the water is dolomitic in the highest degree. For the arguments on either side, except as regards the experience of Sunderland, the reader is referred to Aitken's *System of Medicine*, and Parkes' *Hygiene*, edited by Col. Notter.

Summary of Chapter XI.

The sources of water supply are: (1) Rain collected in tanks or lakes, natural or artificial. (2) Rivers. (3) Springs and wells. In contact with the earth water takes up soluble matters, mineral and organic. **Hardness** is "temporary," *i.e.*, removed by boiling, or "permanent," the former due to calcium carbonate held in solution by CO^2, the latter to chlorides and sulphates of calcium, sodium, magnesium, &c. Hardness is measured in terms of calcium carbonate by the quantity of soap consumed by the salts before a lather can be produced. **Rain water**, and that of lakes, especially when collected from rocky uplands, are pure and soft. All **springs and wells**, especially those in limestone and chalk, are hard. **River water** is moderately hard and contains organic matter, as do shallow wells. Waters are said to be aerated when containing free CO^2 taken up from the soil, the ground water being rich in CO^2, derived from the ground air, and oxygen from the atmosphere. The 10—30% of CO^2 in the ground air is the

product of decomposition of organic matter by bacteria, the nitrates in the soil and the ground water, being produced in like manner. Springs and wells are fed from the sheets of water percolating through pervious, and arrested by impervious strata. If the pervious strata be superficial, wells sunk in them are called "shallow or surface wells," and those sunk through impervious beds to water bearing strata beneath are called "deep" irrespective of their actual depth in feet: they are safe from surface pollution. **Artesian wells** are such as naturally overflow, like fountains, not as the name is vulgarly used, any deep *bored* wells.

The most unwholesome waters are those containing much magnesia, or sulphates and chlorides; **the best** are from lakes or impounding reservoirs on granite, traps or other rocky uplands which are soft, and those from deep wells in chalk, and in carboniferous limestone, often very hard. The oolitic are mostly of high quality, and those from tertiary sands and gravels are good, if protected from pollution, to which surface wells are very liable. Rivers near their sources yield pure water, but lower down always contain much organic pollution.

Chalk waters are softened by Clarke's process, viz., adding "milk of lime" which takes up the free CO_2 that held the chalk in solution.

The **self-purification** of rivers is not a mere chemical oxidation of the organic matter, but the result of the action of animal, vegetable and bacterial life, and of dilution with purer water from affluents and springs.

Water Analysis.—The colour and turbidity having been noticed in a 2 foot tube, any sediment is examined macro- and microscopically, and the water put through a more or less complete chemical examination. The **chlorine** is always estimated in the usual way with silver nitrate and potassium chromate. **Ammonia** is distilled over and estimated by Nessler; the saline having been liberated by sodium carbonate, added before distilling; nitrates and nitrites, the latter best by Griess's test, the former by conversion into ammonia and Nesslerising. The **hardness** by the soap test: **phosphates** and **sulphates** *may* be estimated, but the **organic matter** must. The usual process is that of Wanklyn, in which a part (more or less constant) of the organic matter after the removal of all free and saline ammonia, is itself converted into ammonia by the action of an alkaline solution of potass. permang., distilled over and Nesslerised, under the name of albuminoid ammonia; Frankland's method, more difficult, is simply the ultimate analysis of organic matter into N and C. The amount of O required for the complete oxidation of all organic (and oxidisible) matter is also determined by means of an alkaline solution of potassium per-

manganate. The **total solids** should be distinguished as suspended and dissolved, having very different significance. The **source of chlorine** is often organic, so any marked excess in the absence of sea water, &c., is suspicious. **Nitrates, nitrites and ammonia** indicate complete and imperfect reductions of organic matter. But in all cases the water should be compared with a local standard : and the surroundings of the source studied. **Bacteriological examination** is still more important, for though one may fail to detect typhoid bacilli, a large number of B. Coli is evidence of fæcal pollution and implies the possibility of typhoid, &c.

QUESTIONS ON CHAPTERS XI. AND XII.

1. What are the characteristics of a good drinking water? What effects are likely to follow the drinking of water contaminated by sewage? 1884,E.

2. What is meant by "hard" and "soft" water? Which is the best for domestic use, and why? 1885,E. 1888,E.

3. What is the "constant" system of water service? What are its advantages, and what dangers may be apprehended from its adoption? 1885,A. How may they be avoided?

4. What are improper sources of drinking water for villages and for towns? How may a suspected water be rendered harmless? 1886,E.

5. What kinds of wells are there? What are the characters of the waters yielded by each? 1887,E.

6. How may drinking water be contaminated after delivery in a house? 1887,A.

7. What dangers attach to surface wells, and how may they be avoided?

8. How may the water of streams and rivers be polluted? In which way can such water be purified? 1891,E.

9. Discuss the so-called self-purification of rivers. How is it effected, and what conditions are essential to its occurrence?

10. How are springs formed? What are the usual characters of the waters they yield? 1889,A.

11. Define accurately surface, deep, and artesian wells. Are a less and a greater actual depth characteristic of the first and second? if not, what is the real distinction? Explain the origin of artesian wells, properly so called (not merely bored wells, to which the name is vulgarly but wrongly applied).

12. What are the characters of the waters that have been ascertained to exert a solvent action on lead pipes and cisterns? What measures may be employed to prevent such action? 1891,H.

13. Give the characters of (*a*) rain water; (*b*) water from a spring in the chalk; (*c*) water from a surface well. 1892,E.

14. Discuss the significance of free ammonia and "albuminoid" ammonia in drinking water. Whence are they derived and what may they indicate? 1892, H.

15. What are the sources of chlorides in water? Are they certain indications of urinary contamination?

16. What is the origin and the significance of nitrates and of nitrites in water?

17. Discuss critically the value of a chemical examination of a water? 1893, H.

18. What is meant by (*a*) temporary, and (*b*) permanent hardness of water? How and how far can they be removed? What hardness would you expect to find in (1) a river water; (2) chalk water; (3) water from the lower oolite and lias; (4) the magnesian limestone (dolomite); and (5) peaty moorland?

19. Give the methods of determining quantitatively the chlorides and the nitrates in a water.

20. How are the (*a*) free, and the (*b*) albuminoid ammonia determined quantitatively? What is the significance of the free oxygen and of the oxygen required by the organic or oxidisable matters? and how are they estimated?

21. How may (*a*) surface and (*b*) deep wells become contaminated, and how may the accident be prevented in each case?

22. Describe in detail a method for the filtration of river water on a large scale, and the results produced by it. Discuss the advantages of rivers as sources of drinking water. 1885, H.

23. Distinguish between subsidence, mechanical filtration, and the action of living algæ, and discuss the parts they play in a sand filter basin. Explain how such a "filter" is able to remove a portion of the *dissolved* matters, and under what conditions it fails to do so.

24. Compare the characters of river waters during flood and in times of drought, as regards suspended and dissolved matters respectively, with the modifications required in the "filtering" processes. What treatment before filtration should be adopted in dealing with waters laden with minutely divided clay?

25. What treatment is advisable in the case of chalk waters containing an excessive amount of calcium carbonate in solution, *i.e.*, extreme temporary hardness? Can permanent hardness be reduced in like manner?

26. What materials are used in the filtration of water on a small scale? What is the action of each? What points should be attended to in domestic filters? 1886, A.

27. Describe the principle and construction of the Pasteur-Chamberland filter, and its action. In what respects does the Berkefeld agree with and differ from it?

28. Discuss the efficacy of sand, charcoal, animal, vegetable,

and mineral (coke, silicated carbon, &c.), spongy iron, porous earthenware, asbestos, &c., in domestic filters. At what conclusions have Plagge, Woodhead, and other competent observers arrived as to the value of domestic filters of various kinds?

29. What number of bacteria of all kinds may be deemed permissible in a public water supply? What particular species should be held to condemn a water if present, though in small numbers, and why? Why is that of enteric fever rarely to be detected even in waters known to be contaminated by enteric stools?

30. Why should filtering basins be exposed to air and light, and storage reservoirs whenever possible be covered, apart from the exclusion of dust, &c.? What higher vegetation is especially hurtful?

31. Why should water plants, fish, and, above all, cray-fish, be encouraged in subsidence reservoirs?

32. Describe the action of charcoal as a filtering medium for water. What are its advantages and disadvantages? 1892, A.

33. What are the precautions necessary to secure a pure supply of drinking water from a well? What diseases are believed to be propagated by drinking water? 1896, E.

34. Describe three efficient methods of purifying water, and explain the action in each. 1896, E.

35. Give an account of the chief methods employed for the determination of nitrogen in water. What is the hygienic value of a nitrogen determination? 1896, H.

36. Enumerate the chief sources of water supply, and point out the advantages or objections of each. 1897, E.

37. What dangers may be incurred by storing drinking water in cisterns? Of what materials should cisterns be made, where should they be placed, and how often cleaned? 1898, E.

38. When the service of water to houses is "constant," cisterns are sometimes considered unnecessary. In your opinion is this correct? If not, point out the possible ill results that may follow.

39. What waters may be safely stored in leaden cisterns, and why? How should lead cisterns be cleaned?

40. How may the entrance of vermin, dust, &c., into cisterns be entirely prevented? Describe a cistern at once secure against such accidents, and self-cleansing.

41. Give the composition of a typically good drinking water. State the characters and composition you would expect water to have when drawn from the following sources:—(*a*) Chalk; (*b*) loose sand or gravel; (*c*) upland surface gathering ground; and (*d*) rain. 1898, H.

42. Waters polluted with sewage always contain an excessive amount of chlorides, which are consequently often considered as indicating the degree of such pollution, when not clearly due to

admixture of salt water. Is this correct? The New River water when drawn wholly from wells contains more chlorides than when these sources are supplemented by water pumped from the River Lea. Explain this.

43. Describe in detail the filtration of river water on a large scale, and the results produced by it. Discuss the advantages and disadvantages of rivers as sources of drinking water. 1898, A.

44. What are the characters of rain water? How should it be collected and stored for use? 1899, E.

45. It is proposed to use a river subject to the danger of periodical pollution as a means of supplying drinking water to a large town. State in detail how the water should be collected, filtered, and stored. 1899, H.I.

46. Describe how you would determine the organic matter present in drinking water in terms of the oxygen required to oxidise it. Discuss the value of the determination. 1899, H.I.

47. What is understood by germ-proof filters? Describe one in detail, and explain its action. 1900, A.

48. What do you understand by the term "albumenoid ammonia"? How is it usually determined and what is the value of the determination? 1900, H.I.

49. Describe in detail the method of constructing an impounding reservoir. 1900, H.I.

50. What information, beyond the results of the most accurate chemical and bacteriological examination, is indispensable for a final and trustworthy decision as to the safety of a given water supply?

CHAPTER XII

Amount of Water Required by the Population of Towns

The quantity supplied by the water companies in different towns in Great Britain varies from twelve gallons per head in Norwich to fifty in Glasgow. In Venice and New York it is as much as 300, or practically unlimited. In London the companies supply on an average from twenty-two to thirty-four, but in many of the poorest quarters the actual allowance is under ten gallons.

Water in towns is required not only for drinking, cooking, washing, and other domestic purposes, but for horses

and cows, street watering, flushing of sewers, manufactories, and the extinction of fires, as well as in some places for fountains, &c.

As an approximate estimate of the needs of an ordinary European town population we may give for each inhabitant—

	Gallons.
Domestic use without baths or closets . .	12
Water-closets	6
Baths	4
Unavoidable waste	3
Total house supply per head .	25
Town and trade purposes (including animals) in non-manufacturing towns . . .	5
Additional supply in manufacturing towns .	5–10
	35–40

It should never be less than thirty, and need not be more than fifty. In hospitals a larger quantity is required than in private houses, jails, barracks, &c., on account of the greater amount used for laundry and other purposes, and it should not be less than forty gallons per inmate.

Horses require six to ten gallons for drinking and three for washing.

When it is impossible to obtain a sufficiency of pure water, this should be laid on to the houses to the extent of 20—25 gallons per head, and an inferior supply, as of unfiltered river water, be utilised for municipal, manufacturing and like purposes, but on no account should there be a double supply to private houses. Sea water answers well for street watering and fires.

Filtration of Water on a Large Scale

The water, whether drawn from rivers or from other sources, is first passed into a reservoir or settling basin, where the heavier particles of sand, clay, and other

suspended matters slowly subside by gravitation, forming a muddy deposit. Thence the clearer supernatant water is conducted by a siphon into the filtering tank, the bed of which is composed of a layer of sand two feet thick, beneath which are four successive layers of gravel, each six inches thick, of the size of shot, peas, beans, and walnuts respectively. In the filter beds of the New River Company these rest on two layers of bricks, the upper laid in loose contact, and the lower, at right angles to the upper and with spaces of about two inches left between each row, providing clear channels for the filtered water. From the lowest points of these tanks the water passes through a tunnel into the storage basin, whence it is, if necessary, lifted by a pumping engine to the level of the highest part of the district to be supplied, unless the storage reservoir be at such an elevation as to permit of its being distributed by gravitation.

The upper layers of the filter in time become clogged, and require to be removed to the depth of one or two inches. The sand, after being well washed by agitation in water and exposed to the air, may be used again and again.

It is only as regards the coarser particles that the sand can act as a strainer. Filtration of this kind is rather a process of multiple subsidence, the vast extent of surface presented in every direction by the grains of sand (estimated at 2,500 square yards in each yard cube) attracting and arresting the finest suspended particles.

But this cannot explain the real purification that follows good filtration. This, as Koch and Proskauer have shown, is a biological process, effected by the green felty growth of algæ that quickly forms on the surface of the sand, arresting the bacteria, and assimilating the dissolved matter, especially the organic. A newly made or freshly cleaned filter bed has no such action, and in Germany the filtered water is not served out, but returned to the settling tanks until a fresh growth has formed, and the bacteria have been reduced to 50 per c.c.

It is important to avoid undue acceleration of the flow through the beds by a too rapid withdrawal of the water from the storage basins, on which account the quantity contained in each should not be less than a week's supply, and during rains or floods, when the water of rivers is unusually turbid, it should if possible be much more. The rate of filtration should never exceed two gallons per sq. foot—a velocity of 4 inches per hour.

Filters on the same principle may be constructed on a smaller scale for the purification of rain or other water in detached houses or establishments.

In all such cases the best mode of storing water is in underground tanks constructed of sound masonry, with vaulted roofs, and lined with hydraulic cement. It is thus secured from contamination and from the influence of changes in the external temperature to which cisterns above ground are liable. Thus Captain Galton observed the temperature of a well to vary only between 50·5° and 51·5° during the year, that of the water in the mains between 39·7° and 64·8°, and that of the cistern between 33·6° and 71·5°, showing an annual range of 1° in the well water, 25° in the mains, and 38° in the cisterns.

Constant and Intermittent Supply

It is a common though great mistake to suppose that a constant service implies a boundless supply, and an intermittent a less liberal one. The supply per head of the population obviously depends on the quantity that can be raised daily, and on the dimensions of the storage basins. Every precaution has to be taken, under the constant system, to guard against such wilful waste by individuals as, if generally committed, would stop the entire supply.

In the constant system the mains and service pipes are kept constantly filled, under pressure sufficient to raise the water above the highest stories, and no positive restriction is set on the amount that each householder may draw.

In the intermittent system the water is cut off from the smaller street mains, except for half-an-hour once or twice a day, and when the turncock is called to a fire, though at a number of stations

there are stand-pipes connected with the principal mains which are always full, and where water is at all times to be had for the use of cab ranks, street watering carts, and fires in the immediate proximity. There is also generally a certain amount of dead water under feeble pressure in the mains and service pipes below and for a very few feet above the ground-level, though not rising so high as the house cisterns.

For twenty to thirty minutes daily in each section of the street mains in rotation, the water is turned on with force sufficient to raise it to the highest stories, filling the house cisterns until checked in each by a ball valve or cock.

In the constant system small cisterns are required for water-closets, and are convenient for domestic use while repairs are going on, but the water may be drawn directly from the service pipes. The pipes and fittings are necessarily stronger than in the intermittent system, where a high pressure is maintained for a short time only, during which, too, the ends of the service pipes in the cisterns are open. The companies insist on screw-down taps, and on lead pipes of a particular weight and strength. Thus, the advantages of the constant system are that the pollution of the water by storage is avoided, and that an ample supply is always ready to hand for the suppression of fires, which under the intermittent system frequently extend beyond control during the delay involved in obtaining the services of the turncock.

It is but fair to say that in some places both of these are met under the intermittent system by the erection of hydrants, the seal of which may be broken in case of fire, £5 being payable for so doing, and in the case of courts and poor streets, where it would be vain to expect cisterns to be properly kept, by the erection of one stand-pipe in each, the turncocks being instructed to see that the water is not mischievously wasted.

On the question of waste, the experience of different towns where the constant system has been adopted varies much, some having found the consumption increased, others unchanged or even reduced, these results depending on the habits of the people, especially the practice which prevails in some places of frequently running the cisterns dry. All agree as to the saving of property by having an unlimited supply of water ready to hand in the event of fire, and as to the sanitary advantages there can be but one opinion.

But under all circumstances cisterns must be fitted to all water-closets, not merely in order to obtain an ample and sudden flush, but to obviate the danger of foul air or water being sucked back into the pipes. Indeed, all fittings should be so arranged as to render such an accident impossible, for

though it cannot occur so long as the pipes and mains are full, should the supply fall short a backward pressure or suction is exerted throughout the whole system, and the same result follows locally if any particular section is cut off for repairs or other purpose whenever more than one tap is opened at one time. Foul air, water from lavatories and closets, and even solid fæcal matters have thus been drawn into the mains, and in the case of Caius College, Cambridge, an epidemic of enteric fever was set up by water, thus specifically contaminated, having been turned on again into the houses. Various expedients have been resorted to by the water companies, with a view to prevent the wanton waste incident to the constant service system. Some of these are very reprehensible, such, for example, as the use of taps with very narrow throttles, so that the water does scarcely more than dribble, and householders are really driven to the objectionable practice of storing water in the house in pails, &c., not always clean. Still more to be condemned is the cutting off of the supply for several hours daily, which is open to the same objection and also involves the risk of reflux into the pipes already mentioned.

Service by meter has been generally adopted in contracts with local authorities, manufacturers, and very large consumers; and has been proposed instead of a charge on the annual value of the house in the interest of the occupier. It effectually guarantees the companies against waste, while it permits the most liberal indulgence in water on the part of those who are willing to pay for the luxury. The sole drawback is the probability that the poorer householders would be tempted to stint themselves of this necessary to health and cleanliness, unless, as in some places, a liberal minimum is allowed for a fixed charge, and there is also a difficulty in its application to tenement dwellings.

Water mains are usually made of cast iron, coated while fresh from the foundry with Angus Smith's bituminous varnish, which is cheap, durable, and innocuous; the water may, however, be fouled by defective caulking of the lead joints. Spence's metal employed by some companies avoids this risk, since no oakum or other caulking is required, as it is with lead. Cement joints are liable to leakage. Communicating and service pipes, where the water is found to act on lead, may be made of wrought iron, but Barff's iron would be the better, since it is not acted on in the least by water.

For service pipes lead is almost always employed, though iron has been occasionally used, plain or galvanised.

It has been proposed to line lead pipes with some bituminous,

resinous, or other coating not acted on by water, but it is doubtful how long these would adhere.

Washing the interior with tin has not been found successful, since the thin layer of tin gives at every bend, and the galvanic action set up by the two metals hastens their solution. Block tin pipes cased in lead (Haines' patent), resist torsion, and are fairly successful, but the least fault in connections set up electrolytic action and solution of the metals. Walker's Health pipe (made by Shaw of Huddersfield) seems perfect. It is of wrought iron with a lining of tin which after having been introduced is expanded by hydraulic pressure from within until the two metals appear as if welded into one. Professor Emerson Reynolds states that an alloy of lead with 3 per cent. of tin is not attacked by water, and is used with good results in Dublin and Glasgow, but would scarcely be safe with such waters as act strongly on lead. Lead pipes should never be bent against the grain so as to expose the structure of the metal.

Action of Water on Lead

It would appear from the evidence which we at present possess that the purest water, especially if it contain much free oxygen, acts most powerfully on lead; thus, that of Manchester has been found to contain $\frac{1}{10}$ to $\frac{3}{10}$ of a grain per gallon, and to affect many persons injuriously. In the well-known case of the poisoning of Louis Philippe's family at Claremont, the water which was remarkably pure contained $\frac{7}{10}$ grain per gallon, and as a rule it may be stated that anything over $\frac{1}{20}$ grain per gallon may be injurious. Peaty moorland waters act strongly on lead, and those from the *green* sands of the Thanet beds dissolve lead, iron, and zinc, with more or less rapidity.

But as regards others, the danger has certainly been exaggerated, since ordinary hard waters have no appreciable action on lead. Even at Glasgow, where the purity of the water raised some alarm, no ill results have been observed. And the careful experiments of M. Leblanc at Paris, showed that while distilled water and rain water

dissolved lead, forming crystals of hydrated oxide, no action could be detected from any of the well or river waters of that city.

Carbon dioxide, present in all spring waters, and the sulphates, chlorides, and phosphates of calcium, &c., form an insoluble coating, and protect the metal from further corrosion, though it is conceivable that a great excess of the CO^2 in the absence of other salts may redissolve the insoluble carbonate first formed. The white lead of commerce, a mixture of carbonate and oxide, and red lead, another oxide, are decidedly soluble, and neither should ever be used for stopping joints.

Organic matter acts on lead, another reason why the use of lead for cisterns is to be deprecated, especially since cleaning is apt to re-expose the metal to corrosion. In cisterns the combined action of water with accumulated organic deposit, exposure to air, and warmth, is fraught with dangers which do not attach to the pipes.

Where cisterns are necessary, as under the intermittent system, they should certainly not be made of lead. Zinc is much used in the cheaper class of houses, and is perfectly safe if the water contain calcium carbonate. The same holds good of galvanised iron, so long as the zinc coating is perfect; and iron covered with a vitrified enamel is absolutely free from risk. Slate is one of the very best materials that can be used, but some nicety is required in making the joints, which must never be filled in with white or red lead, but if found leaky made good with cement. Slate cisterns are heavier than galvanised iron, and require a solid brickwork support, but this can hardly be considered an objection. Several firms make cisterns of glazed stoneware, some of them so artistic that they might well be placed in conspicuous and accessible situations on landings, instead of being as usual put out of sight and out of mind. Wooden butts are simply abominable.

Position and Fittings of Cisterns and Service Pipes

Communicating pipes should be laid two or three feet below the surface of the soil, so as to be removed from the influence of frost and sun. Within the house they must in like manner be protected from extremes of temperature, but not by being built into a wall. If concealment is necessary, it should be by means of a removable wooden casing only. The service pipe should be fitted with a strong screw-down stopcock, turned by a key when the pressure of the water is great, or with a handle, when it is less. Each pipe leaving the hot or cold water cisterns, or supplying any separate system of taps, should be fitted with one of the latter kind, that the entire water supply need not be cut off when any part is undergoing repairs.

Cisterns should likewise be secured from frost and sun, as well as from all chance of the entrance of dirt, dust, &c.

Two situations very commonly selected by builders are equally to be condemned—one is in a combined bathroom and water-closet, chosen with the object of saving a few feet of pipe; and the other, for security from frost, is beneath the flooring of a landing or bath-room, where dust, slops, and the like find ready entrance.

The best places are a "box-room," or on the top landing, or where these are not available in the roof, if light, well ventilated, and easy of access. Cisterns on or beneath the leads of a flat roof are objectionable, being exposed to frost and sun, and to the entrance of dead leaves, insects, and dirt.

The supply pipe is always furnished with a stopcock or valve, raised by a floating ball, to cut off the inflow when the cistern is nearly full.

To guard against the accidental failure of the ball

valve or cock, some kind of overflow pipe is necessary, and since the water always enters under considerable pressure, it must, in order that it may discharge the same quantity in the same time, be very much larger than the supply pipe. On no account whatever should it be carried into soil, waste, rain water, or any pipe having any communication with the drains; the interposition of a siphon bend in such cases is utterly useless, for the ball valve may never get out of order, and the trap will then always be dry.

Overflow pipes of this objectionable kind are now happily prohibited. The law requires the overflow pipe to discharge itself in the open air, in some conspicuous situation where it can be seen from the street, or at least such that the householder must in self-defence have the ball valve repaired without delay. They are then called warning pipes.

All drinking cisterns should be cleaned not less often than once in three months, and it is worth while to remember that after heavy rains, the melting of snowfalls, and the breaking up of ice, rivers are more than usually turbid, and the filtration of the water is less perfect. In the hot months of summer again, though the water supplied may be at its best, the suspended matters which tend to accumulate in a cistern undergo rapid decomposition, and the water should at any rate be allowed to run off or the cistern be emptied for garden purposes once a week.

I have designed a cistern inaccessible to dust or vermin, and in which no sediments can accumulate from the water itself. Made of strong galvanised iron plate, like a boiler, it has the form of a vertical cylinder, the base of which is an inverted cone. The close fitting lid has a flange like that of a saucepan, the supply pipe, as well as the overflow, is screwed in to the side of the cylinder, and the service pipe leaves by the apex or lowest point of the conical bottom.

Constant service does not supersede the necessity for cisterns to maintain a reserve in the event of unavoidable interruptions through accident, repairs, or return to intermission during scarcity.

In conclusion, we may repeat that drinking water should, wherever possible, be drawn direct from the main; that cisterns for domestic purposes should be placed out of reach of all imaginable risks of pollution; that separate cisterns from which there shall be no means of drawing water for any other purpose should be provided for the closets; that every part of the water service from the main to the tap should be secured from frost; and lastly, that overflow pipes must be in strict accordance with the requirements of the Water Companies Acts.

There is no doubt that, though diphtheria, enteric fever, diarrhœa, and such blood poisonings as puerperal fever and erysipelas, occurring, perhaps, after vaccination, are most often caused by defective drainage and the entrance of sewer gas into a house, they may also be caused by contamination of the drinking water through old-fashioned waste pipes or other communications between the cistern and the drains.

Before leaving this part of our subject, we may call attention to a prevalent but erroneous notion, that pipes burst in thawing; the fact being, that since water in the form of ice occupies a greater space than in the liquid form, in other words, since it expands in freezing, it is then that the pipes are burst, though of course no escape appears until it returns to the fluid state.

Domestic Filters

However fair in quality the water supplied by the companies may be, there is a general and not unreasonable feeling in favour of subjecting it to further filtration in the house, since, from the nature of the material used in the companies' filtering beds, viz., sand, it is possible that dissolved impurities or even finely divided suspended matters may not be entirely removed.

But as a matter of fact, the majority of domestic filters are

worse than useless, and the purification of the water a delusion, and this is invariably true of the small filters so often seen on sideboards.

The materials employed in their construction are sand and charcoal, or some form of graphite, spongy iron, earthenware, and other porous materials, alone or variously combined. Sand, &c., act mechanically, arresting suspended particles. The carbons, which possess in different degrees the property of absorbing and fixing oxygen, remove or destroy organic matters in a state of solution by a process of oxidation ; but carbon blocks actually serve as hotbeds for the growth of these organisms, which will generally be seen in enormously greater numbers in the filtered than in the unfiltered water. Of course the vast majority of the bacteria are perfectly harmless, but others may be those of specific diseases, and such filtration is obviously a sham.

In the course of his earlier investigations Dr. Plagge experimented with a filter of Swedish manufacture in which the water was subjected to a double process of filtration through specially prepared carbon ; but, though the water used was that supplied to the city from the public service, and contained only 68 bacteria to the cubic centimetre, the filtrate contained 12,000 ! Still more remarkable was the fact that when the second filtering arrangement was removed, the number of bacteria was not more than 1000.

Conducting an inquiry into the merits of different filters for the *British Medical Journal*, Drs. S. Woodhead and Cartwright Wood tested Bischof's Spongy Iron filter exhaustively. They were not content with observing that the water from the two spongy iron filters examined gave on the fourth day at least *ten times as many germs as were contained in the tap water*, but made special determinations of the extent, if any, to which the life of test micro-organisms was inhibited by the filter, as suggested by Mr. Bischof. They found that after a suspension of the cholera bacillus had been passed through the filter, sterile water passed through it became polluted with that organism for eight days, the limit of the experiments, a circumstance which shows that, so far from preventing the contamination of water, this filter is liable, when once infected, to pollute for a considerable time any pure water which may subsequently be passed through it, thereby in the words of the report, "enormously increasing the risk of infection when any of the water used happens to have been infected."

The Pasteur-Chamberland filter (Figs. 26 and 27) consists of a cylinder (*a*) of carefully prepared kaolin and other porcelain clays,

unglazed and tested, closed above, and terminating below in an open nozzle, the base of the cylinder itself being surrounded by a flange. This cylinder is enclosed in a metal jacket (*b*), a space intervening between the two above and at the sides, while below they are fixed together by a screw cap (*c*), perforated in the centre for the passage of the nozzle (*d*), working on the outside of the metal cylinder, and provided with a pair of lateral knobs or buttons by means of which it may be screwed on or off without necessitating the use of pliers. The outer or metallic cylinder is closed above, except where it is soldered on to the water tap, which should be of the screw-down kind; below it is clamped tightly by the screw cap to the flange of the porcelain cylinder, and it is further secured in the vertical position by a band and stay fixed into the wall, not shown in the figure.

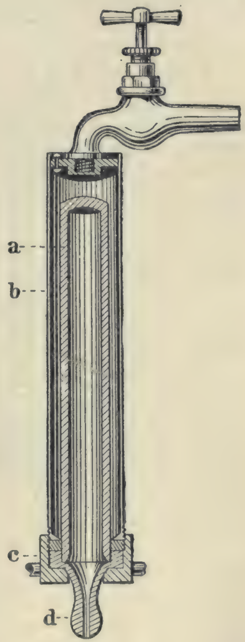


FIG 26.
Section of a Single-cell Tap Filter.

The water passes through the porcelain from without inwards, if subjected to no pressure slowly and in drops, but under a pressure of 1½ to 2½ atmospheres, such as is usually present in the pipes of a public water service, at the rate of two to three quarts per hour; a set of five cylinders would, therefore, be sufficient for the filtration of fifty to eighty gallons daily.

The removal of the screw cap and the cleansing of the porcelain cylinder by brushing under a stream of water from a tap, and afterwards, if deemed advisable, by heating in a spirit or smokeless gas flame, are the work of a few minutes only.

By fitting a number, 10–250, of these "bougies" into perforations in the horizontal diaphragm of an iron drum, which is thus divided into (*a*) an upper or crude and lower (*b*) or pure water

chamber, Messrs. Defries (sole patentees for the U.K.) have adapted the Chamberland filter to the needs of the largest establishments, and by further connecting any number of such drums to the mains for unfiltered and filtered water respectively, they have provided installations for municipal and other public water supplies capable of furnishing several hundred thousand gallons

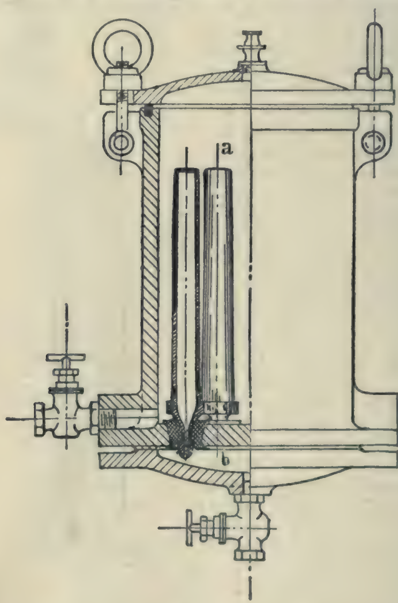


FIG. 27.

Section of a Domestic 10-cell Filter. The largest drums are fitted with 250 cells. One of the bougies is shown in section, the other in elevation.

daily, of absolutely sterile water, the services of one, or at most two attendants being amply sufficient.

The Berkefeld filter differs from the Chamberland in the course of the water, from within outwards, and in the material, Kieselguhr, an infusorial earth, too porous for safety and too friable to resist the frequent sterilisation demanded by its porosity.

The German Trials of Water Filters.

The subject of portable filters has engaged the serious attention of the German War Office ever since the year 1885, when Dr. Plagge issued his first report. Ten years later the question acquired a new and pressing importance in connection with Imperial enterprise in East Africa, and Dr. Plagge having already tested and condemned as utterly useless every description of sand, earthenware, carbon, spongy iron and asbestos filter, repeated his examination of some that had appeared more promising as Schirmer's, Breyer's and Hesse's, the last claiming to be constructed on "Pasteur's principle," but the results showed them to be all alike untrustworthy and wholly unsuited for the purposes of an army in the field or of the private householder.

The Berkefeld filter, from its resemblance to that of Pasteur, and the favour with which it had been received by the British War Office, as well as from the apparent advantage presented by its enormous output, especially attracted his attention, and the greater part of his last report was devoted to the examination of this filter, which he carried on for three years before he finally condemned it as wanting in all the conditions indispensable to security. The *British Medical Journal* in summarising his report wrote :

"The tables extend over sixty pages, and relate to the examination of thirty-eight specimens of Berkefeld filter tubes. Of these, thirty-seven were put into actual use, and examined after periods varying from five days up to six or seven months. The output was in almost all cases found not only to be initially very high, but also with periodical cleaning at short intervals to remain so for long periods. In respect, however, of capacity to arrest microbes, and of mechanical strength, the results obtained may be thus summarised. Of the thirty-seven filters successively set to work, four passed microbes directly, and were consequently not further examined ;

five did so before the end of the trials, varying from five days up to three or four months; one during the trials passed microbes within eight to ten hours from the time of sterilisation; three did so from the outset within twenty-four hours. Of the remainder, sixteen passed microbes within twenty-four hours from sterilisation at some time previous to the termination of the trials, varying from five days up to seven to eight months. In two such cases the filters were examined hourly, and it was found that the organisms passed within the fourteenth and eighteenth hours respectively.

"Dr. Plagge accordingly states that it is necessary for these filters to be sterilised by boiling at least once a day; and he recommends for cases where they may be working during the night as well as the day that they should be sterilised twice every day. The process of sterilising is stated to take from an hour and a half to two hours, it being risky to put the tube into water which is already boiling, or to use it after sterilisation before it has sufficiently cooled, owing to its liability to develop minute flaws. In regard to the mechanical strength of the filter tubes, twenty-seven out of the thirty-seven were broken during their respective trials, varying from nine days to seven or eight months. These results, obtained in the case of tubes submitted by the makers for experiment, and handled by persons accustomed to the manipulation of sensitive appararatus, are probably at least as favourable to the filter as those which would be obtained by persons to whom the care of filters would ordinarily be entrusted in practice. While these experiments were going on, six Pasteur tubes were under similar examination for eight months, but none were broken.

"Plagge's report shows clearly the risks which may be incurred in dallying with alternatives of less efficiency than that of the rigidly adequate standard which Pasteur has supplied."

The Pasteur-Chamberland is still the only filter that is absolutely impermeable to bacteria, and which therefore, though the surface may require cleaning, does not need sterilisation. There is no "Pasteur principle," for its distinctive feature is not the unglazed porcelain cylinder, but the secret composition of the material which, while permitting the passage of water, is so uniformly close in its texture that no bacteria can penetrate it. Almost any filter will yield a sterile filtrate for several hours, and some, as the Berkefeld and Bischof's, will do so for a day or two, but this is simply because it takes two or three days for the bacteria to pass through the substance of the filter, after which they appear in the filtrate, emerging from the further side as fast as they entered the other; and perhaps in greater number, as in the case of the spongy iron, in which they undergo rapid multiplication. The proprietors of each pattern make a display of ostensibly scientific evidence as to efficacy of their particular filters, but they omit to state the period over which the observations extended, whereas a filter that fails to act after some days, unless repeatedly sterilised, is worse than useless, and mere boiling of the water would be far more effective. They always complain of the "unfairness" of unfavourable experiments, though they fail to show wherein the unfairness lay, save in the results not having been in agreement with those of their own *ex parte* claims. It is absurd to suggest that independent men of science like Drs. Woodhead and C. Wood are actuated by interested or hostile motives, and still less that Dr. Plagge, whose sole aim was to find the most perfect filter for the German army, and tested impartially those of French, German, and English makers, was in any way biased, unless that, being entirely satisfied with that of Pasteur, he honestly strove to examine the claims of one, the Berkefeld, by a countryman of his own.

Considering the importance of the issues, *The British Medical Journal* is fully justified in demanding the intervention of the law to put a stop to the promulgation of misleading statements and unfounded claims as to the efficacy of filters, shown to be useless alike by tests in the laboratory and by the fatal results of trusting to them in our armies in the field, and to insist that they shall really accomplish what they profess, or shall not be sold at all.

Summary of Chapter XII.

The **water supply of towns** should never be less than 30 gallons per head daily, 25 being for domestic use and 5 for public purposes ; 40 to 50 may be required in manufacturing towns, but elsewhere more than 35 to 40 is not needed. Unless pumped direct from wells it is allowed to stand in reservoirs holding a week's supply for the subsidence of suspended matters ; it is then passed through sand filters at a rate of 4 in. per hour before being turned on to the mains. The **purification** is not effected so much by the sand, as it is by the film of algæ that grows on the sand, and removes much dissolved organic matter as its pabulum, which no mere mechanical filter could do. Covered **storage reservoirs** are preferable to open ones, protecting the water from heat and frost. The service is intermittent or constant. **Cisterns** are indispensable for the former, and cannot be wholly dispensed with in the latter. Water-closets must have separate service cisterns. Unfiltered or even sea-water may be well used for streets and fires ; the domestic supply should not be charged for by meter, unless an ample minimum be allowed first.

Mains are of iron lined with a kind of varnish ; **house pipes** of lead are in general use and safe with hard waters, but some peaty and other waters dissolve lead. Lead is objectionable for cisterns, which should be of glazed stoneware, slate or galvanised iron ; but red or white lead should not be used for joints.

The **position of the cistern** is almost always bad. It should be protected from heat and cold, dust and vermin, and be easily inspected and cleaned. **Overflow or waste pipes** must never communicate with the drain. Drinking water should, whenever possible, be drawn directly from the house main, not from the cistern.

Domestic filters, with the exception of the Pasteur-Chamberland are delusions, they may clarify the water, but are hot beds for the multiplication of bacteria. Defries supplies grouped Pasteur filters yielding any desired quantity of perfectly sterilised water.

CHAPTER XIII

Scavenging of Towns

In a state of nature, among nomad and thinly scattered agricultural populations, the excreta of men and animals are returned at once to the soil, but when men are crowded in large cities, the disposal of these and of refuse matters generally becomes a problem of the greatest difficulty, but of the utmost importance to health.

Solid excreta and urine are fertilisers of great value to the agriculturist if he can obtain them without undue dilution, but the sanitarian insists on their being removed from amid human habitations as speedily as possible; and water carriage, that is, the conveyance of these in underground channels with and by the force of the waters that have been used for domestic purposes, street cleansing, &c., is found in practice to be the most efficient method, although the excreta are thereby so diluted as to become comparatively worthless as manure.

The matters to be disposed of in towns are :—

Refuse, including

1. House refuse, collected from dustbins and technically known as "Dust."
2. Street refuse, dust, mud, and sweepings, called "Slop."

3. Market refuse, animal and vegetable, together with like refuse from butchers', fishmongers', fruiterers', and greengrocers' shops, and costermongers' stalls.

4. Trade refuse, clinkers, ashes, &c., packing materials, paper, rags, old baskets, &c.

5. Stable manure.

6. Unsound and condemned meat and fish.

Sewage, composed of

1. Fæcal matters and urine.

2. Slopwaters, including the water used in cooking, personal ablution, house and yard cleaning and laundries.

3. Rainfall and water used in cleansing and watering streets.

4. Waste waters of factories, &c.

In this country it is the practice to allow house refuse of all kinds, organic and inorganic, to accumulate in a dust bin close to a door of the house, exposed to the action of sun, air, and rain, until the bulk or the stench of the putrefying mass renders its removal imperative, when the diffusion of foul dust in the process is inconvenient and dangerous.

Dust bins of galvanised iron are clean and very convenient. They can be had at prices varying from 10s. to £1 or more, according to the size, and with or without wheels. But any kind of movable or portable receptacle small enough to be taken off the premises and emptied directly into the cart will do as well, and in poor districts cheap but strong pails might be provided by the authorities.

Nothing should go to the dust-bin but ashes, soot, and broken crockery, or metal ; fowls will dispose of any offal ; otherwise vegetable refuse may be burnt in the kitchen fire, or with animal matters buried in the garden : while bones find a ready sale. Only a strict adherence to this rule can keep the dust-bin from becoming a serious nuisance, if not an actual danger to health.

Manure from stables, cow sheds, &c., if not at once employed in the garden, should be kept on the premises no longer than is absolutely unavoidable. The pits should be of good sound brickwork, entirely above the surrounding ground level, lined with cement and drained into a specially trapped tank or into the sewer. The removal of cow-dung from the pits in town cow-yards, where it putrefies in the accompanying urine and foul liquid, is a most disgusting operation, creating a pestilential stench, though, as every one knows, the same manure in a meadow, where it is exposed to the air and dries on its surface, is per-

fectly inoffensive. Great difficulty is now found in London in the removal of stable manure, on account of the cost of carriage to the country, where only it can find a market, and it is much to be desired that the railway companies could be induced to convey it at reduced charges in trucks owned by the sanitary authorities.

Ashes are in great demand where and when building operations are proceeding rapidly, but in large towns the supply soon exceeds the demand, and the question of their carriage also comes into account.

As collected from the dust bins they contain a large admixture of organic matters of all kinds, from cabbage stalks up to the entrails of fish, and these have to be separated. Whether the sanitary authorities themselves undertake the entire work of scavenging or entrust it to contractors who engage the requisite labour, receiving so much per load and the proceeds of its sale, the procedure is the same.

The contents of the dust bins, from all parts of the district, are piled up in some centrally placed dustyard where they undergo putrefaction, and give off a loathsome stench. Meanwhile they are sifted by wretched women, whose persons and clothes are black with filth, breathing the rank fetid vapours, and half buried in the dust at which they work. The "breeze" or fine ash is sold or given to brickmakers; the "hard core," clinkers, broken crockery, &c., is used for road-making; while the "soft core" or animal and vegetable refuse is added to the collected stable manure. Iron, tin, paper, rags, bottles, corks, &c., are carefully separated and sold by the contractor. In Paris all these things are the perquisite, in fact the only renumeration of the *chiffoniers* or rag and dust people; whereas, here, "totting," or previous picking out of the saleable parts by the collectors, is strictly forbidden, and as a consequence there is much difficulty in getting the men to visit "dead" streets, *i.e.*, those poor streets where they cannot expect gratuities.

An interesting experiment may be seen at the works of the Refuse Utilisation Co., 20 King's Road, Chelsea, where the "dust" is sorted and sifted mechanically in closed drums instead of by hand labour, and the items are to some extent utilised on the premises, a coarse brown paper being the chief product.

A practice which cannot be too strongly deprecated is frequently resorted to by unprincipled contractors and builders of using the unsorted contents of dust bins, largely composed of animal and vegetable matters, for filling in the excavations caused by the

removal of sand and gravel previous to building houses on these soils. This is prohibited in London by the Public Health Act of 1891.

In some places the refuse from fish shops and slaughter-houses is collected daily by the makers of chemical and artificial manures, who are also ready to receive meat and fish which have been condemned as unsound in the markets: but in large towns their disposal is attended with greater difficulties than is that of stable manure, owing to the cost of carriage; and they, as well as the "soft core," are in London mixed with the horse droppings from the streets, depreciating the later as manure.

In a well ordered establishment, in which everything that can be burnt without creating effluvia is so disposed of, and the animal refuse is utilised in one or other of the ways we have indicated, the house refuse would be reduced to a very small bulk, and where there was a kitchen garden the visits of the dust cart would be unnecessary; but since this thrift is rarely practised, and in towns there must always be a large quantity of street and market, as well as house refuse, the only solution of a problem which now taxes to the utmost the resources of the local authorities is to be found in the application on a large scale and with special apparatus of the same principle, that of burning everything that can be burnt. It has already been tried with success in Leeds, Bradford, Manchester, Rochdale, Warrington, Stafford, Bolton, Blackburn, Bury, Derby, Rotherham, Nottingham, &c.

Two or three distinct apparatus are required for the thorough carrying out of the system, the most important and the essential one being the "destructor" invented by Mr. Alfred Fryer, of the firm of Manlove, Alliott, Fryer & Co., of Nottingham, by which the whole of the "dust" is reduced to a quarter or one sixth of its original bulk, without any sifting or manual labour beyond the removal of metallic articles. This residue, consisting of ash and of clinkers, may be used as such for road-mending, or be ground by a pug mill worked by the waste heat of the furnace, to a powder, which, mixed with lime, makes an excellent cement. The small amount of fuel required to set the furnace working is furnished by the fine coal and cinders always found in the "dust," and the furnace being smoke-consuming, neither dust, smoke, nor offensive vapour is allowed to escape into the atmosphere around.

It must be admitted that the destructor has in some towns been found less satisfactory than in others, requiring additional fuel to effect complete combustion, and occasionally even giving rise to complaints of effluvia, &c. But this is owing to a want of

regard having been had to the nature and composition of the local refuse and to adapting the procedure to these special conditions.

The "carboniser" invented by the same gentleman is intended for the disposal of the vegetable refuse from markets, which it converts without any nuisance into charcoal of a good quality, selling readily at 20s. per ton, and at a merely nominal expense after the first cost of erection.

If the demand for charcoal be not sufficient to call for a separate treatment of vegetable refuse, the destructor is quite capable of disposing of it, and even of human or animal excreta should they not be required for manure.

The question, however, of the profitable disposal or employments of refuse as manure, depends on the proximity of lands likely to be improved by its application and on the opportunities for cheap carriage. Thus the "Newington Mixture" compounded of "slop," "dust" and stable dung finds a ready market in poor stiff clays of certain parts of Kent.

In some places, where marshes or foreshores are open to reclamation, it would be the best policy to forego all present proceeds, by "shooting" the whole crude mass of refuse until a sufficient depth of land be obtained for commencing drainage and agricultural development.

In the East end of London a horrible mixture of bad fish, butchers' offal, gulley slop, &c., is carted to the Essex farms, emitting a pestilential stench and believed by the villagers and Medical Officers of Health to be a cause of diphtheria and other forms of disease.

Firman's rotatory rendering machine, patented by the same firm, reduces the contents of middens and pails, as well as offal and condemned meat, to a brown powder, devoid of odour and nearly dry, of high manurial value, in fact an artificial guano, and may be so modified as to separate the fat in a form fit for the purposes of the candlemaker and soapboiler.

Where much meat is condemned, as in the principal seats of the foreign cattle and dead meat import trade, these apparatus may be supplemented by the addition of one of Dr. Sedgwick Saunders' "Devils" or carcase-crushers, which will reduce a horse to mincemeat in about thirty seconds. The entire mass, crushed bones and all, is then introduced into a Firman's rotatory rendering machine, the flesh and fat separated from the bones, the fat later extracted from the flesh, and this finally reduced to the guano above mentioned.

Street Sweepings and Mud.—The composition and quantity depend very much on the weather and the nature of

the paving, the water varying between 35 and 90 per cent. and the dry solids containing on an average 50 to 60 per cent. of horse droppings, 30 to 35 of powdered stone, and 10 to 15 of iron. The inorganic matter is enormously increased both relatively and absolutely, and the organic relatively reduced in wet weather especially on granite cube pavings where the mineral *débris* is produced not so much by the attrition of the granite surface as by working up from below; hence the importance of having a good concrete bottom. Macadam gives the largest and wood or asphalt the least amount of mineral mud. It is also remarkable that the more thoroughly and frequently roads are cleaned, especially by the mechanical sweeper, the less is the quantity of mud removed not only at each sweeping but in the course of a long period, and a considerable saving in the cost of materials and repairs is thus effected by the use of these machines.

Disposal of Excreta and Slops

Human Excreta.—An adult man passes daily 3 to 4 oz. of fæces and 40 to 50 oz. of urine. Women and children excrete less, so that for a mixed population 2½ oz. of fæces and 30 to 40 oz. of urine per head may be taken as a fair daily average. It is not unusual to speak of these as solid and liquid excreta respectively, though, in fact, far more solid matters are passed, in solution, by the kidneys, than are present in the fæces. Sir J. Lawes and Dr. Gilbert estimate the fresh fæces of an adult man at 4·17 oz., and the urine at 50·18 oz. When dried the fæces weigh 1·041 oz., and the urine, when evaporated to dryness, 1·735. Thus the total excreta consist of solids 2·776 oz., and water 51·574. The manurial value of the urine is six times as great as that of the fæces, so that any arrangement which allows the former to run to waste is economically a mistake.

Both urine and fæces are acid when passed, but in time become alkaline from the change of urea into carbonate of ammonia. Pure fæces decompose very slowly, and urine remains unchanged for days, but when they are mixed with water decomposition sets in

within twenty-four hours, evolving carbonate of ammonia, ammonium sulphide, hydrocarbons, and fetid organic compounds. After two or three weeks the mixture becomes very viscid; but the viscidity is lessened by dilution with water and prevented by carbolic acid.

Slop waters and waste waters of all kinds will, in towns provided with public water-works, approximately equal the amount supplied together with not less than half of the rainfall—such errors, as loss by evaporation from the surface of roads, casual sources, as "drainage of lands," wells, &c., being left to neutralise one another.

The volume of the rainfall is obtained by multiplying the depth as indicated by the rain-gauge into the acreage of the drainage area.

Such being the sources of the watery constituents of sewage, it will easily be understood that the presence or absence of fæcal matters makes but little difference in its foulness, for domestic slop waters contain urine, soapy, greasy, and other solid matters from kitchen, scullery, and laundry, and the washings of streets, yards, stables, &c., are charged with manure and filth of all kinds.

One ton of London sewage contains only two or three lbs. of solid matter, and its value as manure has been aptly compared to a few grains of gold in a cart load of sand. Indeed, the sewage of towns without water-closets is often more concentrated, for the volume of water used to wash down each dejection more than compensates for the additional solids of the fæces introduced.

Before proceeding further we will define certain terms often confused in popular language, but which technically and legally have definite significations.

The word *drain* has two distinct meanings. It is the name applied to all channels or pipes used to carry off the superfluous moisture from the soil, whether the land be devoted to pasture, arable, garden, or building purposes.

But in the present connection it means any drain belonging to a single house or premises, and conveying the waste waters, &c., to a cesspool or to a common sewer. A *sewer* is a drain belonging to the local authority, and common to a number of houses—"house drains, and street sewers."

Sewerage is the provision of sewers to a town, as *drainage* is of drains to an area or to houses. *Sewage* is the foul water conveyed by the sewers.

Where the system of water carriage as it is called, or in other words, of water-closets and sewers, has been introduced into a town, these matters are disposed of together; elsewhere, as in villages and in towns where the pail, midden, or other system still holds its ground, two separate problems are presented. In rural districts at the present time, and in towns in many parts of the Continent, the excreta are allowed to accumulate in cesspits, while the slop waters are either thrown on to the garden ground or into the yard or road to find their way by some rudely constructed gutter or drain to the nearest watercourse, unless previously absorbed by the earth.

Indeed the sewers of bygone days were not intended to carry anything else than the slops of houses and the rainfall, and it is no wonder that, flat-bottomed or roughly barrel-shaped, pervious and ill-laid, they proved utterly unequal to the additional work thrown on them by the general introduction of water-closets.

The oldest form of privy, still met with in cottages in the country, was simply a hole dug in the ground for the reception of solid and liquid excreta, the fluid parts of which soaked into the soil, or if the house were on a higher level than the road, made their escape at some weak point, and trickled down in a black fetid stream to the gutter, while the semi-solid residuum was carted away when the cesspit became inconveniently full. In porous soils, as the chalk, oolite, or gravels, this point

was rarely reached, the absorption of the liquid and the decomposition of the more solid matters keeping pace with their accumulation for an indefinite time; indeed, one at New College, Oxford, constructed in the time of William of Wykeham, was not emptied until fifty years ago, and in many places twenty years is considered by no means too long an interval. The consequences of such soakage into the neighbouring wells are obvious.

When cesspits are made impervious to fluids more frequent emptying becomes necessary, and their contents are more fluid and proportionately more offensive; but the climax is reached when, by the adoption of water-closets, the fecal matters are largely diluted with waste and slop waters. Such cesspits are worse than the ancient privy and deserve unqualified condemnation.

We need not follow the various steps by which the old fashioned privy has been improved on, but shall merely describe the pail system as now worked in many towns in the north of England.

Beneath the seat stands a pail, oval or round, so as to be easily cleaned. A shoot provided with a sieve opens at the back of the privy; into this the ashes from the grates are thrown, the cinders being arrested and used again, while the fine dust falling into the pail covers the fæces, and serves to deodorise them; a separate pail is provided for kitchen refuse, and the contents of each are removed by the scavenger at frequent and regular intervals. The space under the seat is reached by a door at the back, and the pail covered by a close fitting lid is removed and replaced by a clean one into which a little disinfecting fluid has been run.

At Halifax the Goux system has been tried, but with very doubtful advantage. It consists in lining the pail with an absorbent composition of ashes, charcoal, and clay, pressed into shape by means of a cylindrical mould. For a day or two it works well, but the absorbent lining soon becomes saturated, diminishing the available space, and adding to the labour and cost of removal. The pail is a great improvement on the old privy, but no system involving the retention of fecal matters in and around dwellings in towns can long be deemed satisfactory, and

in Birmingham as well as other places the pails are being fast superseded by serviceable hopper closets.

It is however quite different with cottages in rural districts, where there is garden ground and open space.

Earth Closets

The absorbent and deodorising action of earth on decomposing organic matter is well known. It depends on oxidation processes, involving the conversion of the ammonia compounds into which animal substances are resolved into nitrites and nitrates, and is effected by the agency of minute organisms or bacteria. It is possessed in very different degrees by different soils, being most active in moderately dry and loose loams or garden soils, and least so in clay or gravel and sand. The Rev. E. Moule was the first to suggest its application to the present purpose. In earth closets, of which there are now several patterns some of them acting automatically, each dejection is immediately covered with about $1\frac{1}{2}$ lb. of the earth previously pulverised and sifted. When the pail is full its contents are at once applied to the field or garden, or removed to a heap in a shed open to the air, but protected from sun and rain, where, after having been frequently turned over by the spade, the earth may be used again, as many as six to twelve times, before its virtues are exhausted.

In country houses, farms, asylums, &c., where there is plenty of space for storage of the earth, and where the services of a regular attendant under intelligent supervision are available, the earth closet is a decided success, but it is, for many obvious reasons, totally inapplicable to the requirements of town populations, and, unless carefully seen to, is not free from smell, so that it can rarely, if ever, be tolerated inside a house.

Since the action of the earth is to nitrify the organic matter, the product is rather of the nature of a guano than of ordinary manure; indeed, earth that has been used six or seven times is little richer in crude organic matter than good garden mould.

Ashes, on the other hand, absorb, but do not oxidize, as does basic slag, which has been proposed as a substitute, a lesser volume being required, and being itself a valuable fertiliser.

For country houses, large or small, the course we should recommend is that pursued with the very best sanitary and economic results at the Penmaen Workhouse in the Gower Peninsular in South Wales, and by Dr. V. Poore at his houses at Andover and Isleworth, and described in his *Rural Hygiene*, where the solid excreta and urine mixed with ashes are daily removed and applied to the garden, and the slops are also daily poured on to a small patch of grass land. The crops raised in the vegetable garden are enormous, and the inmates enjoy excellent health.

If the owner of a mansion must have water-closets, the entire sewage, including slops, should be conveyed by a drain to a distant meadow and disposed of by irrigation, or, where the kitchen garden is sufficiently remote from the dwelling, to a cess-pit consisting of a shallower and a deeper chamber separated by a vertical grating, solid bodies being arrested in the former; while the fluids draining into the lower compartment are distributed by a pump and hose over the garden. The cesspool must, however, be far from the dwelling, disconnected by an intercepting shaft and trap and perfectly impervious to fluids, being lined throughout with hydraulic cement. Such an arrangement closely resembles the treatment of town sewage in "septic tanks."

The practice of some eminent architects and otherwise sound sanitarians of conducting the sewage of such houses to a brook which may be the source of drinking supply to cottagers, is most reprehensible; and its disposal through porous subsoil drains or sumps, below the zone of vegetation and nitrifying bacteria is not much better, endangering the surface wells in the vicinity.

Pneumatic Methods of Removing Excreta.

In many foreign towns where the waste and slop waters are removed by the ancient sewers, and pails have not taken the place of cesspits, these are emptied by pneumatic means instead of by manual labour. A large cylinder, or several small ones on wheels, and exhausted by an air pump, are connected with the cesspit by pipes. On the stopcock between being opened the contents of the cesspit are sucked up into the cylinder, which, if not full, can be exhausted of air for a fresh charge. These cylinders are certainly preferable to the old night soil cart, but the existence of cesspits in towns should not be tolerated in the present day.

Captain Liernur of the Dutch Royal Engineers has developed the pneumatic method in a most ingenious manner, by substituting for the movable apparatus an underground system of pipes and cylinders. Small tanks are connected with separate blocks or lines of houses at intervals along the streets, by means of main pipes. These are made to communicate with larger tanks, which are connected in like manner with a central tank at the sewage works. The connecting pipes are provided with stopcocks, like those on the water mains in our streets. A powerful engine working an air-pump maintains a constant vacuum in the central tank, extending through the communicating pipes to the secondary tanks. Every day the turncocks, by opening the stopcocks, discharge the contents of the street reservoirs into the district tanks, and in the same way from these into the central one, from which it is pumped out and manufactured into poudrette. It is claimed in favour of this system, which has been adopted in several towns of Holland, that no nuisance is created, and the full manurial value of the sewage is obtained, and that it does not preclude the use of water-closets. On the other hand, it is urged that a separate system of sewers is required for slops and foul surface waters from the streets, that it is impossible in this system to maintain efficient water seals in traps between the house and the street, and that no suction can remove the filth that adheres to pipes which can never be flushed. Its success, even where carried out under the immediate supervision of the inventor, is by no means certain, but the violent and unfair advocacy of its promoters makes it impossible to obtain anything like trustworthy information.

Berlier and others have contrived systems of pneumatic removal of excreta, monuments of perverted ingenuity.

Summary of Chapter XIII.

Disposal of Refuse.—Town refuse is not easily disposed of, that from stables, streets and markets may be taken by farmers, and "dust" from houses by brickmakers, after sifting. Refuse should not be used for building sites. Where not saleable it is best burnt in a "Destructor," and offal may be converted into artificial guano.

Excreta, are classed as solid and liquid, but urine yields $1\frac{3}{4}$ oz. and fæces 1 oz. dry solids daily, and the former has six times the manurial value of the latter. London sewage contains but 2—3 lbs. solids in a ton, and that of towns without w.c.'s is often richer than that of those with them.

Drains are for houses, **sewers** for streets, **sewerage** is the system or provision of a system of sewers, and **sewage** the liquid removed by the sewer. "Drains" and drainage are also applied to the removal of surface, and lowering of ground water. Thus drainage of land, sewage of towns, and drainage of houses. **Privy or cess-pits**, always more or less pervious, pollute ground-waters and wells. **Earth closets** or pails should be substituted, but in large establishments with w.c.'s deep water-tight tanks with pumps for distributing the fluid may be erected at a distance. Cesspits requiring carting of contents are intolerable.

QUESTIONS ON CHAPTERS XIII. AND XIV.

1. What are the advantages and disadvantages of the water carriage system of removal of excrement? 1884,A.
2. What chemical methods have been proposed for the purification of sewage? Upon what principles do they depend? What results have been obtained? 1884,H.
3. What refuse matters are produced in a kitchen? What should be done with each of these? 1886,E.
4. On what principle does the dry earth system for the treat-

ment of excretal matters depend? Under what circumstances should its adoption be recommended? 1889, H.

5. Give a short account of the treatment of town sewage by a precipitation process, stating the results you would expect. 1890, A.

6. Describe a destructor furnace for the disposal of dustbin refuse and other matters. What nuisances are likely to be caused by it? and how may they be prevented? 1890, H.

7. Describe a method of rendering inoffensive, and available for manure, condemned meat, market refuse, and the contents of pail closets, &c.?

8. What evils are likely to attend the discharge of sewage into (*a*) tidal rivers; (*b*) non-tidal rivers; and (*c*) the sea? 1890, H.

9. What inconveniences follow the entrance of the rising tide into sewers, and how are they obviated?

10. How should dustbins be constructed, and where should they be placed? What kinds of refuse should not be put into them? 1891, E.

11. Define the terms "intermittent downward filtration" and "irrigation" as used in the disposal of sewage. What are the conditions required to ensure success in each of these methods? 1893, A.

12. Discuss the question of so-called "sewage farming" from the sanitary and economic standpoints.

13. How should a cesspool be constructed? Describe under what circumstances it should be used, and the arrangements you would make for its connection with the house. If possible, illustrate your answer with a sketch. 1895, A.

14. What is the best method of disposing of excreta in villages and isolated cottages so as to avoid contamination of wells and pollution of streams?

15. What dangers are inseparable from cesspits as usually constructed? What objections exist to the sewerage of villages not provided with public water supplies or with numerous water closets? Does any danger attach to the direct application of excreta and slops to the garden soil when there are shallow wells as water supplies to the cottages? and, if not, explain why.

16. Distinguish between the direct application to the soil of the fresh excreta and the contents of earth closets and of ash closets.

17. What are the comparative advantages and disadvantages of the "dry" and "wet" method of sewage removal? Describe in detail one system of dry removal. 1898, A.

18. Describe a good form of joint for sewers in a water-logged soil. How should sewers be ventilated? 1900, A.

19. What are the advantages of "portable" over fixed dust-bins?

20. What dangers may follow the construction of sewers so as to act as drains for the removal of subsoil waters? How should the latter process be provided for in laying sewers?

21. Explain the superiority of the egg-shaped sewer over the barrel or other forms.

22. Discuss the respective merits, sanitary and economic, of the "combined" and the "separate" systems of sewerage. How is the rainfall provided for in the latter? What are "storm overflows" in connection with the former, and what the character of storm waters in towns as compared with sewage?

23. Compare the sewage of towns with and without water closets as regards composition and foulness.

24. What are "intercepting" sewers? What are the disadvantages of very steep gradients in sewers? and how should the sewerage be arranged in towns, parts of which are at elevations considerably greater than others?

25. What is the d fference between "sewer air" and "sewer gas"? In a well-made sewer how does the sewer air compare with ordinary air? 1900, A.

26. What do you understand by the "biological" methods of treating sewage? 1899, A.

27. Describe in detail the "bacterial filter" and the "bacterial tank." What is the nature of the process that takes place in (*a*) the tank and the "coarse filter," and in (*b*) the "fine filter"? What are the characters, chemical, &c., of the respective effluents? Compare the former process with that occurring in cesspools of houses with water closets, and the latter with that in "downward intermittent filtration."

28. Why is the sludge in the bacterial methods insignificant in quantity, and quite inoffensive? Is it, in your opinion, advisable to subject the final effluent to earth filtration before the discharge into a river?

29. What is the composition of sludge in (*a*) untreated sewage, (*b*) that arrested in the bacterial tank, and (*c*) that produced in the sulphate of alumina, the lime, and the ABC processes?

30. To what extent may ordinary sludge be reduced in bulk and weight by natural drying, pressure, and heat? Under what circumstances may the sludge be turned to account in the application of sewage to land?

31 What dangers are incident to burial (*a*) in the earth, (*b*) in vaults, and (*c*) in churches? Have those of ordinary graveyards to the health of the neighbourhood been exaggerated? What soils are the most and what the least fit? Why are those

in the heart of cities unfit? What are the objections to leaden coffins in earth burial?

32. Discuss the advantages of cremation, and the validity of the objections raised to it as offering facilities for the concealment of crime. How may they be obviated? Can all poisons be detected by examination after exhumation of a body?

33. What is meant by the statement that the chemical treatment of sewage is "unscientific, opposed to the economy of nature, and, as regards precipitation and sterilisation, aiming at the unattainable"? How far does it follow that it is therefore to be altogether condemned?

34. Describe Shone's Ejector and the advantages it presents in the sewerages of towns on low lying and level sites.

35. What gradients are best for (*a*) main sewers, (*b*) street sewers, and (*c*) house drains? What ill effects follow very steep gradients?

36. What is the best velocity for sewage? and what inconveniences follow lower and higher velocities?

CHAPTER XIV

WATER CARRIAGE SYSTEMS

In each of the methods hitherto described the aim has been to utilise to the utmost the manurial value of the excreta, and there can be no doubt that this is the proper course in rural districts and country towns where land under cultivation is always at hand, where carriage is cheap, and where it is of special importance to preserve the purity of small rivers and streams.

But in large and densely peopled cities where the reverse of all these conditions exists, where houses are crowded and kitchen gardens unknown, and where the

street washings, slop and factory waste waters are as foul as sewage itself, it is no less certain that the water carriage system, though it does not pretend to utilise the sewage, presents enormous advantages, both sanitary and economic. Pails may still be provided by the authorities for the use of the very poor and reckless classes who cannot be trusted to keep water-closets in a proper state, though it is quite possible to procure closets that cannot get out of order, except through malicious injury, which might be made penal, as it is under the new Public Health Act for London.

That sewerage systems as too often carried out, and defective arrangements for the connection of the closet and house drains with the sewers, have in many places, notably in London itself, led to an increased prevalence of enteric fever, diphtheria, and diseases of like origin cannot be denied ; but these consequences must not be laid to the account of the system, since they might easily be prevented by greater care in construction of sewers, by by-laws regulating that of house drains and sanitary arrangements enforced by strict supervision.

Main Sewerage Works

In the construction of these either of two courses may be followed—the combined system, or, as the French call it, the "*tout à l'égoût*," and the separate system. The latter does not, as some imagine, attempt to obtain the excreta in a concentrated form, as Captain Liernur's does, but merely aims at excluding the rainfall from the sewers, on the principle expressed in the phrase, "Rain to the river and sewage to the soil."

The *tout à l'égoût* seems at first sight to have the advantage of simplicity, since in the other some arrangement must be made for conveying the rainfall to the nearest water-courses, but, both on sanitary and pecuniary grounds, it is open to grave objections.

The sewage of a population is a known and constant quantity, being practically the same as the water supply, varying only with the hours of day and night, and in a less degree with the season of the year. It is therefore easy to construct sewers of such a diameter that they shall never be either too full or nearly empty.

The rainfall, on the other hand, is irregular and uncertain. It is practically impossible, if it were desirable, to build sewers of sufficient capacity to carry off the sudden torrents of water accompanying thunderstorms, and if it is sought, as in London, to make them large enough to accommodate the sewage and the *ordinary* rainfall, they present during prolonged droughts a vast reservoir of sewer gas, while during storms the swollen waters force the foul air through every opening, and rise into the house drains, flooding the basements in low-lying districts, and occasionally bursting the sewers themselves.

To avoid this catastrophe the excess of rainfall ought to be provided for by carefully planned surface drains, or by storm overflows, which are of various forms but consist essentially of collateral channels communicating with the main sewers at a level considerably above that of the ordinary sewage stream.

These accidents are especially apt to occur when different parts of a town are at very different elevations. In all such cases the sewage from the higher ground should be carried off independently of that from the lower, or if the sewers have been originally improperly designed, an intercepting sewer may be carried more or less transversely along the contour line of the hills, as has been done at different levels in London. Another objection to sewers at very different gradients in successive sections is, that a rapid current in the upper part becomes a sluggish one below leading to deposits of silt.

Intercepting sewers serve another purpose, viz., that of preventing those carried down the hillsides from acting as shafts to the lower ones and conveying gases into the

houses above. Sewers in such positions should terminate in a ventilating shaft or open head, and be ventilated at frequent intervals in their course.

The points to be aimed at in the construction of sewers—

1. To ensure as uniform and constant a velocity of the flow as is possible under varying circumstances.

2. To regulate the velocity so that it shall be strong enough to keep in motion any solid bodies that may gain entrance, but not so strong as to cause needless wear of the masonry.

3. To avoid the deposition of silt and banks of sediment especially at the junctions.

4. To avoid back-watering or the stagnation and reflux of the stream under certain circumstances.

5. To maintain the greatest possible purity of the air in the sewer, and

6. To prevent its entrance into houses.

To secure a uniform flow we must diminish friction so far as is possible, and this is effected partly by careful workmanship and partly by the choice of such a figure as shall maintain the ratio between the depth and volume of the stream on one hand, and the wet surface of the sewer, *i.e.*, the bottom and sides of the stream, on the other. Without entering into technical details as to the thickness, method of binding, etc., of the brickwork, we will simply say that the bricks should be set in hydraulic cement made from blue lias and not grouted, and that the interior should be smoothly finished with the same so as to be quite impervious and free from the least inequality. Glazed earthenware inverts are often used for the lowest segment, and are decidedly preferable to brickwork in that position. Sewers were formerly made flat-bottomed or circular; barrel-shaped sewers are with great difficulty rendered water-tight, and flat-bottomed ones cause the maximum of friction and deposit (Fig. 28).

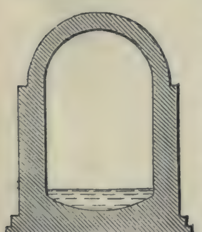


FIG. 28.

By universal consent all brick sewers should be egg shaped, narrow end down. The egg shape is formed by two circles

touching one another, such that the diameter of the upper equals twice that of the lower, the sides of the figure being completed by arcs drawn from points, as centres on either side, on a level with the centre of the upper and larger circle, and at a distance from the circumference of this circle equal to its radius, *i.e.*, to the diameter of the smaller circle. (In practice this point is found to be slightly below the level indicated. Fig. 29). Thus

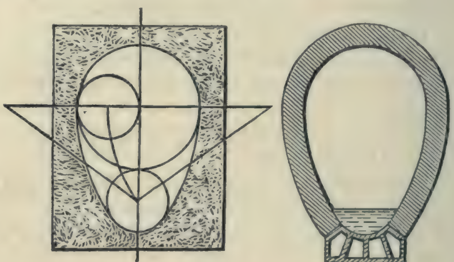


FIG. 29.

this radius equals the sum of the diameters of the component circles, *i.e.*, the depth of the sewer.

Thus if B = Diameter of bottom of sewer, *i.e.*, of the smaller circle.
C = Diameter of top of sewer or larger circle.
R = Radius of sides.
D = Depth of sewer.

$$B = \frac{D}{3} \qquad C = \frac{2D}{3} \qquad R = D$$

For practical mensuration the area is taken as that of an ellipse, with semi-axes equal to D and C, the lesser magnitude of B being disregarded.

HYDRAULIC MEMORANDA.

We may here give the formulæ for the mensuration of circles and ellipses. The circumference of a circle is $3\frac{1}{7}$ times the diameter or twice $3\frac{1}{7}$ times the radius; the decimal expression being 3·1416 or π.

Thus if r = the radius of a circle, and a and b the semi-axes of an ellipse, the circumference of a circle $= 2\pi r$, and its area $= \pi r^2$.

The circumference or perimeter of an ellipse $=\pi(a+b)$ approximately, and its area $=\pi ab$.

An arc of a circle subtending A°

$$=\frac{A}{180}.\pi r$$

and lastly, the area of a circular segment

$$=\pi r^2.\ \frac{A}{360}-\tfrac{1}{2}r^2 \sin.\ A.$$

A being the angle of the sector. The last two formulæ are less frequently called for in simple problems.

The advantage possessed by the egg-shaped sewer is, that when the depth of the stream is diminished, the wetted perimeter, the friction producing factor, is proportionally reduced, instead of being as in every other form of sewer relatively increased.

The next desideratum, the regulation of the velocity, is attained by adapting the fall or gradient to the size of the sewer.

A continuous flow of 2 feet to 2 feet 6 inches per second is sufficient, though if liable to variation a mean flow of 3½ feet is needed to prevent deposit ; but 4 feet should not be exceeded, for one of 6 feet per second, if there be much sand or grit, is found to wear away the brick-work of the sewer.

As a general rule the fall should be 1 in 240, though 1 in 600 has been found fairly successful, with frequent flushing, but when the fall is less, deposits occur, and resort must be had to pumping to accelerate the movement of the sewage.

The relation between size and velocity may be thus stated.

Over 36	inches	diameter	2½	feet	per second	=150	per minute.
18—36	,,	,,	3	,,	,,	=180	,,
6—18	,,	,,	3½	,,	,,	=200	,,
Under 6	,,	,,	4	,,	,,	=240	,,

Hydraulic mean depth is an expression used by engineers, a clear apprehension of which is necessary for the solution of all problems concerning the velocity and capabilities of sewers, though it is either ignored or left unexplained in mathematical text-books and ordinary works on sanitation.

It means the depth of a rectangular channel whose sectional area, and therefore the volume of whose current equals that of the curvilinear channel under consideration, and whose width equals the entire wetted perimeter of the latter.

Thus if the line drawn from one bank of a river to the other along the *bottom* of the stream is 100 feet, its hydraulic mean depth is the depth of a rectangular channel 100 feet wide which would have the same sectional area as the river, and would therefore carry the same quantity of water. It is defined as "the sectional area, divided by the wetted perimeter," since the depth of the corresponding rectangular channel would be equal to its sectional area divided by its width, which by hypothesis is the same as the wetted perimeter of the river.

For circular pipes, whose diameter we may take as 1, running full, the sectional area will be the area of the circle $= \pi r^2$, and the wetted perimeter will be its circumference $= 2\pi r$; while for the same pipes running half full, the halves of these or $\pi r^2 \div 2$ and $2\pi r \div 2$; in either case the hydraulic mean depth is one-fourth of the diameter of the pipe, for the

$$\frac{\text{sectional area}}{\text{wetted perimeter}} = \frac{\pi r^2}{2\pi r} \text{ or } \frac{\frac{\pi r^2}{2}}{\frac{2\pi r}{2}} = \frac{r}{2} = \frac{1}{4}$$

In other words, the depth of a rectangular channel corresponding to, and having a width equal to the wetted perimeter of a semicircular one will be half that of the latter, or one-fourth of the diameter of a circular one.

For depths greater or less than the half of a circle, the arcs and segments to be added or subtracted can be determined only by trigonometrical methods, and are rarely required in practice.

1 cubic foot of water $= 62{\cdot}425$ lbs. $= {\cdot}028$ ton $= 6{\cdot}24$, say $6\frac{1}{4}$ gallons.

1 gallon $= 10$ lbs. $= {\cdot}16$ cubic foot.

1 ton $= 224$ gallons $= 35{\cdot}9$ cubic feet.

H = head or height of water in feet.

P = pressure in lbs. per square inch $= \text{H} \times {\cdot}4335$ and $\text{H} = \text{P} \times 2{\cdot}307$.

The pressure per square foot is of course $\text{H} \times 62{\cdot}425$.

The following formulæ are used to determine the velocity of the flow in egg-shaped sewers and the discharge:—

x = hydraulic mean depth in feet.	V = velocity in feet per minute.
f = fall in feet per mile.	A = area in square feet.

C = cubic feet of water delivered per minute.

then $\text{V} = 55\sqrt{x \times 2f}$ and $\text{C} = \text{V} \times \text{A}$, 55 being an empirical constant.

There is a simple and useful formula by Mr. Blackwell, in

which allowance is made for ordinary friction. V = velocity in feet per second; D = diameter of pipe in feet; and H = inclination of pipe in feet per mile.

$$\text{Then } V = \sqrt{\frac{DH}{2{\cdot}3}},\quad D = \frac{2{\cdot}3\ V^2}{H},\quad H = \frac{2{\cdot}3\ V^2}{D}$$

Two other formulæ may be given for sewers running two-thirds full. The length (l) and fall (f) of the sewer, as well as the diameter of a circular pipe or of the larger cirele of an egg-shaped sewer (d) being known. The discharge in cub. ft. per second = Q. For egg shaped, $Q = 35\sqrt{d^5\frac{f}{l}}$; and for cylindrical, $Q = 25\sqrt{d^5\frac{f}{l}}$ the 5th powers are given in engineering tables, as Molesworth's.

Any of these formula may be used for calculating velocity (V) of water in feet per minute in rectilinear channels, but it is generally necessary to ascertain the additional head or pressure required to overcome the friction presented by Knees and bends, in order to maintain the desired velocity, or to allow for the retardation of the stream thereby. H being this additional head, V the velocity in feet per second, and C the coefficient of friction, $H = {\cdot}0155\ V^2 K$ for angles or knees.

The value of K for different angles (knees) is as follows—

A°=	20°	40°	60°	80°	90°	100°	120°
K=	·046	·139	·364	·74	·98	1·26	1·86

For bends—

$$H = {\cdot}0155\ V^2 \left(\frac{A}{180}L\right)$$

The value of L when the pipe is of the same uniform diameter throughout, is for circular sections 2, and for rectangular sections 3·2, but by enlarging the bore of the bend the friction may be greatly reduced. Into these details we need not enter here.

To avoid deposition of sediment at junctions it is imperative that these should be made as oblique as possible, and since streets are usually at right angles with one another, the branch sewers should describe a wide and gentle sweep, approaching a quarter of a circle, before entering the main one, otherwise a bank of silt will form at the meeting of the two currents.

Back-watering is inevitable when sewers discharge into the sea,

or into tidal rivers. This is to be guarded against first by self-acting flaps or lock gates at the mouth of the sewer, and secondly by providing a basin into which the sewage may flow during the hours that the mouth of the sewer has to be closed, and this again may demand means for pumping out the accumulated sewage in the meantime.

There are, however, such serious objections to the discharge of sewage in these situations, that such contrivances can be looked on as temporary expedients only to be superseded so soon as possible by some other means of disposal.

So long as sewage flows in a steady stream, and no deposit takes place, the air of a sewer is comparatively pure ; any offensive odour is proof positive of decomposition, which can occur only when the sewage has time to stagnate, or where deposits of filth are formed. That this need not be the case is shown by the fact that in Frankfurt-on-the-Main, where the sewers are of the usual kind, egg-shaped, and receiving sewage and rainfall, with moderate gradient, but of admirable construction and regularly flushed, it has never been necessary for a man to enter to remove deposits, whereas in London several hundred labourers are constantly employed at this work.

Where the land is so level that to obtain a sufficient fall in a sewer of considerable length it would be necessary to carry it towards its termination to an inconvenient depth, the sewers should be made in shorter sections, and the sewage pumped from the end of one into the head of the next. Pumping is also required when the sewage is disposed of as at Berlin, by irrigation over land on the same level as the town. In this case a pumping station is necessary ; but in the former, and in the drainage of single buildings when the drains are laid at the same depth as the sewer, the automatic ejector of Mr. I. Shone is preferable to the employment of ordinary pumps.

The Shone system, in which any number of ejectors, acting by means of compressed air, can be worked from a single central steam-engine presents obvious advantages. It is not that compressed air is less expensive than the ordinary steam pump, but that the cost of each ejector being small, and their action automatic, one engine sufficing to work a number of ejectors, the sewers may be divided into numerous sections each having an ample fall so as to employ the aid of gravitation to the utmost advantage.

The ejector is a horizontal cylindrical reservoir, erected in a vault beneath the roadway or other ground level, the pipe sewers entering and leaving it being furnished with inlet and outlet ball valves, and the former having the form of a siphon. The com-

pressed air tubes are conducted along the upper flat outer surface of the reservoir. When the sewage has risen to the top of the reservoir, it acts by means of a float on a counterpoised lever, opening a valve and admitting the compressed air, which, closing the inlet ball valve while it raises the other through the pressure on the fluid, rapidly and forcibly ejects the whole of the sewage into the further length of pipe sewer; when the sinking of the float closes the valve of the compressed air tube, at the same time opening another for the escape of the now expanded air until the sewage again fills the ejector. Alone or combined with automatic flushing it is well adapted for use in large establishments as hospitals, the drains of which are more or less complicated and perhaps connected with unsatisfactory sewers.

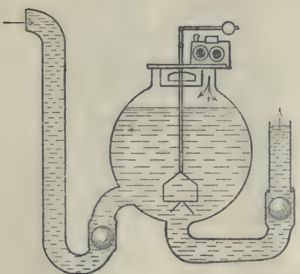


FIG. 30.

It would be well if the distinction drawn by Pettenkofer between *sewer air* and *sewer gas* were more carefully observed. The former is innocent and may be odourless, the latter offensive and dangerous to health, and is always the result of stagnation, deposit, and putrefaction.

Sewers should always be freely ventilated, and the fouler the air the more necessary it is to provide for its escape, for it is impossible that it can be kept from forcing its way into the houses if free exit be not given to it somewhere else. Ventilators of adequate size should be provided at intervals of not more than 100 yards, and may consist of grated openings in the roadway. It has been proposed to use the lamp-posts for the purpose, that the foul air may escape above the heads of the passers-by and be speedily diffused, but the present form of lamp-post is scarcely large enough. In some places a ventilating pipe is carried above the roof every house, and in others special shafts have been erected at the heads of the sewers.

Whether these openings will act as inlets or outlets depends on the relative temperature and density of the air in the sewer and in the street. The former is warmer in cold weather and cooler in hot; the varying volume of the sewage, too, causes efflux or influx, forcing out large volumes of foul air when it

suddenly rises in consequence of heavy rains. The more freely the sewers are ventilated the less will be the difference of internal and external temperature and barometric pressure. This explains the conflicting statements founded on observations in different towns, and repeated regardless of the differing circumstances.

The entrance of sewer air or gases into houses is preventible by complete disconnection of the drain from the pipes, whether soil or waste, in the house, and by this means only. The way in which this disconnection is effected has been described under the sanitary arrangements of the house itself.

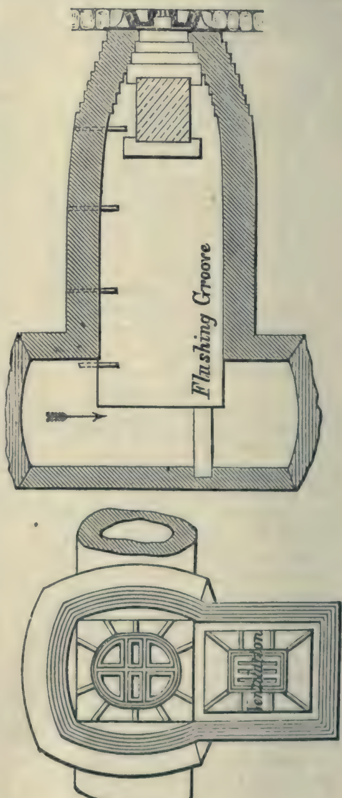


FIG. 31.

To admit the rainfall into the sewers with as little as possible of the grit and refuse of the streets, gulleys are provided at intervals in the course of the gutters. These are, shafts 2 or 3 feet deep, communicating with the sewer by a pipe a little below the grating, which serves to exclude large stones and sticks, the opening of this pipe being closed by a valve that allows the passage of water while checking the escape of foul air in inconvenient proximity to the footway and the houses.

The mud and grit that collects at the bottom of the shaft is cleared out from time to time.

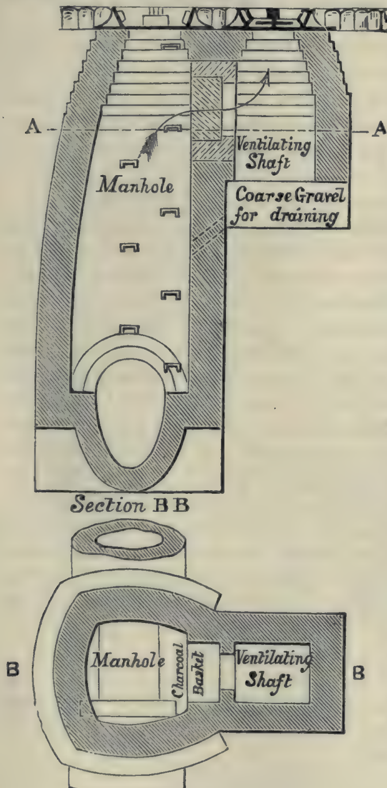


FIG. 32.

Access to the sewer for the purpose of removing deposits or for repairs is provided by manholes of the form shown in the accompanying figures. (Figs. 31 and 32.) The hole is covered by an iron lid, and the men effect the descent by hand irons fixed in the wall of the shaft. At the side of the manhole is a ventilator, a screen of two frames of wire work with charcoal being sometimes interposed. This may serve to some extent, while the charcoal is fresh, to absorb foul-smelling gases, but presents a serious obstacle to the ventilation, and as we have already asserted, such deodorising screens ought to be needless, and are but evidences of ill-constructed sewers.

THE SEPARATE SYSTEM.

Advocated forty years ago by the father of sanitary reform, the late Sir Edwin Chadwick, K.C.B., this system has long been successfully

worked at a few places, though legislation insisting on the right of manufacturers to discharge their wastes into the sewers has prevented its more general adoption.

The best example on a large scale is to be found in the city of Memphis, in America, which had been so frequently ravaged by cholera and fevers that its entire abandonment was actually contemplated, when Colonel Waring undertook to render it healthy by cleansing and filling up the cesspits in the porous rock, and carrying out the system of sewerage under consideration.

He provided for the carrying-off of the rainfall, which, in the Mississippi Valley, is very heavy, by surface gutters and drains following the natural declivities of the site to the lagoon, and then constructed a system of cylindrical sewers for the removal of excreta and slop waters only. The houses were effectually disconnected from the drains; the house drains, of 4 inches diameter, ventilated by pipes carried above the roofs; the street sewers, also cylindrical, had a calibre of not more than 6 or 8 inches; while a few mains of 12 inches and one larger culvert completed the system. Besides the ventilating shafts attached to each house drain, others were provided at every junction and at the head of every main sewer, fifty in number, where as many of Rogers Field's automatic flushing tanks, fed by the waste of drinking fountains, &c., were fixed, discharging at intervals of six hours 150 gallons of water in about five or six minutes, and effectually cleaning out the sewers.

The cost was incomparably less than that of the ordinary system would have been, and the results so satisfactory, that the example of Memphis should be very widely followed.

Sewage Disposal.

The disposal of the huge volume of foul waters carried by the sewers out of the town is one of the most difficult problems of sanitary administration. The most obvious

courses are to discharge it into rivers or the sea, but to say nothing of the waste of matters which were intended in the economy of nature to be returned to the land whence they were originally derived and in which their place must be filled if it is still to yield its produce, the pollution of rivers is a source of the greatest possible danger to the health of the community, and the discharge of sewage into the sea is not altogether free from annoyance.

Attempts may therefore be made at effecting its purification by processes of filtration and chemical treatment, so far at least as to permit of its being poured into a river without danger or serious offence ; or, lastly, we may endeavour to utilise it by returning it to the land, if such can be found capable of receiving so large a volume of water, and of destroying so much of the organic matters as is not assimilated by the crops.

Discharge of Sewage into the Sea

It might seem as if the sewage of the most populous city would be but the proverbial "drop in the ocean," and so it would be were sewage a mere watery solution, obeying the laws of the diffusion of fluids. But such is not the case, sewage contains not only a large quantity of insoluble matters held in suspension, but also of albuminoid substances which are coagulated by the action of the sea salt, and form a glutinous mass arresting and holding in suspension the solid particles that otherwise would have sunk to the bottom.

Besides the ebb and flow of the tide there are, as every one who has been in the habit of boating or swimming knows well, on every coast secondary currents setting alternately in opposite directions, with intervening periods of rest. By these the sheet of sewage is carried to and from the shore, and up and down the coast, resting in still waters and gradually settling down to form a black slimy deposit on and in the sand, as may be seen at too many of our seaside resorts. The grosser particles indeed are eagerly devoured by fishes, but this putrid slime is most injurious to the fisheries in estuaries and channels as well as everywhere detrimental to the interest of the towns on the coast.

It is not enough to carry the outfall beyond low water mark, for these currents extend further and deeper, and in fact the condition under which alone the Local Government Board approves the discharge of crude sewage into the sea, viz., "that no nuisance is caused thereby," can be found only where, if anywhere, there is a constant current in one direction and that seawards.

Besides, the rising tide forces the sewage back into the sewers, and the sewer gases into the streets and houses unless its entry be prevented by flap valves or sluices, when the sewage stagnates and accumulates in the sewers unless ample reservoirs be provided for its reception during the rise of the tide, these tanks again being a source of nuisance and expense.

Discharge into Rivers

The discharge of sewage into tidal rivers is followed by the same consequences in an aggravated degree. The dark offensive cloud sweeps up and down the stream, which it never leaves, except partially during floods, and it deposits in the bed of the river and on the foreshores a black fetid mud exhaling pestilential odours when exposed, especially in warm weather.

In the higher reaches the current is, indeed, constant in the same direction, but unless the river be, like the Rhine or Danube, far larger and more rapid than any in this country, its pollution soon becomes a danger and a nuisance, and such rivers cease to be available as sources of public water supply.

The self-purifying power of running streams has been considered already (see pp. 279, 280).

Purification of Sewage.

Before sewage can be discharged into rivers without danger to health, it must be subjected to some process of purification. Irrigation in the form of downward intermittent filtration, though it has failed to realise the dreams of golden harvests entertained by its earliest advocates, remains unrivalled for efficiency. But it is, save in a few places, difficult, if not impossible, to secure in the vicinity of great cities suitable and sufficient land, and between 1870 and 1890 a number of chemical processes were proposed and tried, none of which, however, proved really satisfactory. They are without exception wrong in principle, being opposed to the economy of nature, and as regards precipitation and sterilisation, aiming at the unattainable.

What measure of apparent success has followed the employment of some of these procedures must be ascribed to their having acted in the manner about to be described, for there is no evidence that spongy iron, polarite, &c., possess, at any rate after the first few days, any properties than those common to coke and similar inert porous materials. They may therefore, one and all, be dismissed as unworthy of serious consideration, and where irrigation is impracticable, the choice of a sanitary authority is restricted to one or other of the bacterial methods, the filters, the tank, or a combination of the two. The open filter acts as a medium for the culture of nitrifying aërobic bacteria, in the same way as the soil, while the tank and the deep, dark, coarse filter favour the growth of anaërobes, whose function is to digest or peptonise and to reduce to a state of solution the suspended organic solids that otherwise constitute a large part of the sludge, rendering them thereby more susceptible to the action of the aërobic and nitrifying bacteria, effecting in a few hours their resolution into their inorganic constituents, a change which from the slowness of the former stage in the soil, would take many days or weeks in the natural earth.

The idea of the artificial culture of bacteria was first conceived by Mr. Scott Moncrieff, whose results were confirmed and explained by the experiments of Mr. Dibden. The nitrifying function of aërobic bacteria in the soil had been originally demonstrated by Schlössing, Wollny, and Müntz, in Germany, as the peptonising action of anaërobes was by the Commissioners on Sewage purification appointed by the State Board of Health of Massachusetts.

The Bacterial Filter.

The sewage after passing through a coarse screen and detritus tank is run into the coarse filter, a deep tank half filled with coke, clinkers, porous limestone, or even hard burnt ballast in pieces of 1 to 2½ inches in diameter, where it is held up for eight to twelve hours; from this the effluent is conveyed to the fine filter tank, wider and shallower than the former, the filtering materials being screened to ¼ to 1 inch, there it is retained for three or four hours, or better for one hour in each of as many filters in succession, after which it is discharged into a river with or without previous filtration through a well drained plot of land.

The action of the coarse and fine filters is well shown by the chemical examination of their effluents, that from the former containing little oxygen or nitrates, whereas that from the latter is rich in both, especially in nitrates.

The Bacterial Tank.

In the process devised by Mr. Cameron, of Exeter, a bacterial, or, as he calls it, a septic tank, is substituted for the coarse filter, for the better effecting of the peptonising of the solids. In it the sewage, coarsely strained, passes very slowly through long tanks, closed against air and light; with a sunk wall shutting off a first compartment as a catchpit for earthy sediment. Here the suspended particles of organic matter are, as it were, digested or peptonised, and dissolved by the action of anaërobic bacteria, *i.e.* those thriving in the absence of air or oxygen: and the effluent having lost nearly all its oxygen, retaining very little suspended solids, but with far more in solution than was in the sewage, is again aërated by being run over a weir and cascade arrangement and finally passed through filters of limestone and coke breeze where the albuminoid matter is nitrified by aërobes, until the filtrate is fit to be discharged into a good sized river, though it should, whenever practicable, be previously passed through well-drained land or over water meadows.

Chemical Treatment.

All "precipitation" processes consist essentially in the addition of alum, which, decomposed by the ammonia in the putrefying sewage, throws down the flocculent aluminium hydrate; this entangles the suspended organic solids, depositing them as sludge, the ammonia fixed as a sulphate passing with other soluble matters into the effluent. In some processes lime also is added, in the ABC blood clay and charcoal, and in one the phosphate of aluminium is substituted for the sulphate (alum). All add to the sludge and none "mineralise" the dissolved matters, whereas the bacterial filters dissolve the solids and nitrify the organic ammonia.

Other processes, as the ferrozone, aim at the oxidation of the organic matters by the oxygen supposed to be absorbed by the spongy iron and charcoal, but these more probably act as the bacterial filters, though less perfectly, while the "amine" process, in which herring brine (!) is used, emitting an intolerable stench, attempts the sterilisation of the effluent, which putrefies after dilution into a river. The "Hermite" process seeks to disinfect it by the evolution of nascent chlorine and hypochlorous acid, and the electrolytic to bring nascent oxygen to bear on it, but this and the "Hermite" are unworthy of serious consideration.

Irrigation

Although the natural soil makes an efficient filter, its characteristic and peculiar action is not simply mechanical but rather vital or physiological. The surface soil, to a depth of three, four, or at most six feet, the "living earth," as it has been happily described by Dr. G. V. Poore, swarms with bacteria whose function it is to convert the ammonia, into which all albuminous matters are resolved, into nitric acid, which then combines with the alkaline and earthy bases in the soil, and is taken up by the vegetation.

It is by means of these bacteria following on those to which the processes of ordinary putrefaction are due, that all putrid animal matters are sooner or later rendered innocuous by being converted into simple inorganic salts.

All soils possess this power more or less, except *pure* sands and *plastic* clays; but the former soon acquire it if mixed with clay, mud, or anything that may transform them into soil. Indeed it is merely necessary to work in the sludge and crude sewage to convert tracts reclaimed from the sea into filter beds or irrigation fields which will become more efficient every year. The adaptation of clay is more difficult, but may be effected by burning, and digging in sand, chalk, or ashes until a fairly loose and pervious soil is obtained.

In applying sewage to land we may avail ourselves of the soil solely as a filter, using the smallest possible area equal to the purification of the sewage, and dismissing all thoughts of raising vegetation for profit; or, on the other hand, we may employ an area so large that it shall be capable of taking in the entire sewage without detriment or with benefit to the crops or pasture to which it is devoted. This latter system is often called "sewage farming," but the term is somewhat misleading, suggesting that it is undertaken as a commercial speculation, whereas the primary and essential aim is the thorough purification of the sewage, so that the effluent may be passed into a river without a suspicion of ill-results; and pecuniary returns, it must always be borne in mind, are a secondary consideration. Such farming can rarely prove a source of profit in the ordinary acceptation of the word; but if the produce recoup an appreciable part of the yearly expenditure, while the cultivation of the land greatly enhances the efficiency of the process of purification, all has been achieved

that can or indeed ought to be expected. Only in poor, light deep and thirsty soils would a farmer, as such, think of employing enormous volumes of very dilute manure all the year round, though he would everywhere gladly accept the manure without the water, the excreta as distinguished from the sewage. Except in unusually dry seasons the excess of water positively detracts from the success of the system from an agricultural standpoint, and the best economy will always be found in the devotion to this purpose of the greatest extent of land that can be secured, even though other manure should have to be supplied; indeed such an extensive sewage farm might provide for the utilisation of a considerable part of the street, house, and market refuse of the town.

Filtration, in the narrower sense, is permissible only under special circumstances; for unless the soil be little if any better than bare sand, like the dunes and banks enclosing the lagoons along the Prussian coast or the Craigentinny meadows near Edinburgh, it is very apt to become waterlogged or sewage-sodden, when nitrification ceases and is succeeded by putrefaction, and the effluent may be worse than the fresh sewage.

Sewage farming embraces at least two distinct procedures.

Firstly, downward intermittent filtration. The land is laid out in successive terraces, along the upper side of each of which is a channel or carrier made in concrete; from this smaller channels, the feeders, are made with a drain plough or spade at regular intervals across the land, and the sewage is turned on to each fourth section in rotation every six hours, so as to allow of its percolation, and the subsequent aëration of the soil before the next charge. The soil is well worked and drained by porous earthenware pipes at a depth not exceeding six feet, and the effluent from these should, whenever it can be arranged, be allowed to run over a water meadow before finally entering a river. These prepared lands are well suited for growing root crops, as beet, mangel-wurzel, swedes, &c., and also for most culinary vegetables.

Secondly, broad irrigation or the frequent submergence of large areas is chiefly applicable to permanent pasture, and the affluents from the irrigation beds may be thus turned to account. With ordinary grasses this cannot be carried on continuously, though in dry springs heavy crops may be raised by free watering, and generally a second cutting or aftermath secured in

September. Rye grass, sorghum, and maize are however, capable of imbibing enormous quantities of liquid, though available only for green fodder.

Effluents not wholly depurated may be advantageously employed in forming water-cress beds, which may be let at nominal rents to the poor.

Fruit trees may be planted on the margins of the irrigation beds.

Among the crops best adapted for irrigation farms are roots (except potatoes, which do best in drier soils), gourds, cauliflowers, and lettuces. Also juicy green fodder as saintfoin and vetches, and lastly, Italian rye grass, the most thirsty of all. The lightest soil should be given to carrots, which thrive in pure sand if supplied with abundance of water.

By a judicious selection of crops there would rarely be any difficulty in making the proceeds cover the working expenses, as has for some time been the case at Berlin, the most perfect and successful as well as the largest undertaking in the world, if we exclude the exceptional instances already referred to of worthless sandy wastes reclaimed and made productive. Where complaints are made of nuisances of any kind arising from sewage farms, it is always owing to the unsuitability or the insufficient extent of the land under treatment, or to ignorance or negligence in the conduct of the work. The superintendent should be a scientific and practical farmer, assisted by an intelligent engineer, and the committee of management should include men acquainted with the several aspects of the question.

As at Berlin, there need be no fear of injury to the health of the surrounding population, or when experience has overcome sentimental objections and prejudice, of any permanent deterioration of the neighbouring property.

SECTION III.—RIVER POLLUTION

The general introduction of sewerage has produced an evil scarcely less than that it has removed, for in proportion as the soil of our towns has been made more wholesome the rivers have become polluted. It is true that the local authorities are gradually being compelled to adopt measures for the purification of their sewage, but these are often very imperfect, and there remains untouched the sewage of countless riverside villages and houses which passes in its crude state into our streams, so that

very few can be used with perfect safety as sources of public water supply.

But another, and in the northern counties especially, even greater cause of pollution is to be found in the discharge into the rivers of factory wastes, a practice favoured by the facilities presented by the sewers for its ready removal.

The Rivers Pollution Act was meant to remedy this, but besides bristling with saving clauses and limitations, it cannot but remain a dead letter so long as its execution is committed to local authorities, in which the manufacturers, themselves the offenders against its provisions, exert a preponderating influence. It is rarely that they seek even the certificate of an inspector of the Local Government Board as to "the best practicable and available means" of purifying their waste waters, although in nearly every industry these might be, and sometimes are, rendered comparatively harmless, with considerable pecuniary profit from the recovery and utilisation of the chemicals they contain. The Rivers Pollution Commissioners fixed certain standards of purity under which waste liquids should not be discharged into rivers, but these are easily fulfilled in the letter by dilution with water pumped out of the river itself, an absurd and useless procedure. What is wanted is an official declaration of the "best practicable processes" for treating each kind of waste for the time being, and a standard of purity based on the analysis of the river water above and below the point of discharge.

At present the water of the Irwell is considerably fouler than the crude sewage of some towns, and mountain streams like the Aire and Calder are converted into open sewers. During flood the waters are turbid with suspended impurities, but as a rule the pollution is greatest in times of drought, when the dissolved organic matters reach the maximum, as seen in the analyses on page 355.

Woollen mills furnish by far the filthiest of all wastes, containing, besides alkalies, dyes, and mordants, an enormous quantity of grease, which, if recovered, might be a source of considerable profit, being the raw material whence lanoline, the elegant basis of so many toilet preparations and ointments, is "made in Germany" and more recently in Australia.

Tanneries are nearly as bad and more palpably offensive, but they are fewer in number and confined to certain localities.

Paper mills alone have to any great extent adopted satisfactory measures for purifying their waste. What it was, and is still

occasionally, may be imagined when one mill alone recovers by means of the Porion Evaporator twenty-four tons of soda weekly, besides sixty tons of putrescible organic matter. The saving in soda alone repays the cost of the apparatus in the first or second year. Probably the improvement has been forced upon the owners by the fact that from the necessities of the manufacture these works are mostly located on the banks of the purest streams in rural districts.

	River Irwell				Tottington-Brook in Drought.	Sewage.	
	Drght.	Norm.	High water.	Flood.		Leeds Sewage.	Salford Sewage.
	Parts per Milln.	Parts per Milln.	Parts per Milln.	Parts per Milln.	Parts per Milln.	Parts per Milln.	Parts per Milln.
Suspended . . .	26·0	164·8	132·7	679·0	342·2	899·0	12859.7
,, Fixed (mineral?)	10·7	70·2	96·0	505·4	237·2	224·0	3203·0
,, Volatile (organic?)	15·3	94·6	36·7	173·6	105·0	675·3	9656·7
Soluble solids .	857·	728·6	528·8	314·2	4200·	1257·0	1371·4
Hardness . . .	271·4	271·4	260·0	168·5	700·	271·4	231·4
Chlorine	117·1	106·5	55·7	25·2	471·5	139·4	456·4
Alkalinity in terms of H^2SO^4	196·	215·6	117·6	98·	490·	313·6	248·9
Ammonia . . .	9·6	7·8	4·5	1·6	3·16	28·8	14·7
Album. Amm. .	2·9	2·5	1·9	1·1	7·34	4·0	5·5
Nitrates	1·6	6·	1·2	·4	1·24	1·8	1·1
Absorbed Oxyg.	137·6	116·8	60·	28·4	1864·0	180·0	176·13

Cotton, calico, and linen mills yield a waste containing much alkali, size, and fermenting starch, though some have adopted the Porion Evaporator with the best results, sanitary and economic.

Dye works cause great discoloration of the water, but do not add very much to the organic pollution, while *bleaching and even chemical works* do less harm than is commonly supposed. Bleaching powder increases the hardness and the chlorine, neither of which however tend to favour putrefaction.

SECTION IV.—DISPOSAL OF THE DEAD

Notwithstanding the exertions of a small party of reformers in favour of cremation, it is in the highest degree improbable that, for many generations at any

rate, there will be any appreciable change in the practice of interment, sanctioned as it is by usage, sentiment, and prejudice.

Interment, or inhumation, is based on the action of the bacteria present in the soil, of converting organic matter into nitrates, and otherwise resolving it into simple so-called inorganic products. Any conditions which prevent or delay this change defeat the intention of interment, and should be, so far as possible, avoided. Such are sepulture in vaults, whether within churches or in cemeteries, the use of more or less imperishable coffins, and the choice of clay and other soils impervious to air. Happily, save in exceptional cases, burial in churches is wellnigh obsolete ; but it is much to be desired that the substitution of cenotaphs or monuments and memorial tablets were everywhere made compulsory, for the escape of the emanations from corpses into buildings crowded with the living is alike repugnant to decency and dangerous to health ; and it is more than doubtful whether such escape can be prevented by any known means, some bodies undergoing a process of desiccation, or mummification, and others, under apparently identical circumstances, liquefying and putrefying, changes to be averted only by embalming by antiseptic injection—*cui bono?*

Viewed in this light, lead or other metallic coffins stand self-condemned. Even the hard woods, oak, elm, and teak, are objectionable, for, as was seen when, during the construction of the Holborn Viaduct, excavations were made through St. Andrew's Churchyard, the bodies buried 200 years ago were in a state of putrefaction little more advanced than those interred only twenty years previously, when the place was closed by Act of Parliament. The wood, a non-nitrogenous material, resisting decay, protected from the same process the bodies which, from the pressure of the superincumbent soil, were, so to say, "sandwiched" between layers of partially disintegrated wood : and only those who have been present at such a function as the removal of the bodies from St. James's Churchyard in the Hampstead Road can conceive aright the horrors of intramural burial.

Coffins were unknown almost throughout Christendom for

more than 1000 years, and not generally used until the fourteenth or fifteenth centuries. If they must be retained, they should be of the most perishable materials, light deal or, still better, basket work, as advocated by the "earth to earth" system.

The selection of a site is of the utmost importance, for while in soils pervious to air and moisture, as sandy loams or chalk, bodies undergo such rapid *decomposition* that in eight or ten years nothing but the bones and hair remain, in clays and waterlogged soils they slowly *putrefy*, presenting, thirty or forty years afterwards, a fetid mass of slime and fat; and it is difficult to conceive anything more repugnant to all human feeling than the chopping up with the spade of such remains every twenty years or so in the portions of the metropolitan cemeteries set apart for those who cannot afford the luxury of a freehold grave.

A site should be chosen remote from dwellings, with a soil suitable for the purpose, and be well drained and planted; the ground-water must not be allowed to rise higher than twelve feet from the surface, nor the bodies be buried at less than four feet, nor below ten, since at greater depths, even where above the water-line, nitrification is slow if it occur at all.

Wells interposed in the course of and fed by ground-water that has percolated through the zone of graves must be highly contaminated, though filtration may have rendered it clear to the eye, and it may be sparkling with the carbonic acid evolved in the decomposition of the bodies. But the danger arising from the supposed poisonous character of the air of graveyards has been greatly exaggerated. In a well-chosen soil and site the gases given off consist almost wholly of CO^2, which is entirely taken up by the vegetation.

The fatal consequences of descents into long-closed vaults have probably been due to the accumulated CO^2 of the ground-air irrespective of the proximity of corpses, and identical with those that have occasionally been observed in descending deep, disused, and covered wells.

But the general influence on the surrounding earth, air, and water of intramural graveyards, especially with impervious soils and more or less imperishable coffins, the earth charged with organic matter far in excess of what it can resolve into its constituent compounds, and perhaps raised some feet above the adjacent street by the accumulation of corpses and coffins, is dangerous in the extreme, and a disgrace to civilisation.

In large towns the expense of transit to distant extramural cemeteries is severely felt by the independent poor, who shrink from the thought of a pauper's funeral; but it might be overcome by the maintenance at the public cost of a service of funeral trains at "workmen's fares," with a branch line and terminus in the cemetery. These should run at stated hours daily or otherwise, while first or second class fares might be charged for corresponding superior accommodation.

The best, indeed the only perfect cemetery near London is that of the Necropolis Company at Woking, where site, soil, and arrangements are all that could be desired, and where a crematorium has also been provided.

Cremation

When we reflect on the fact that in the course of every forty years accommodation has to be found in the immediate vicinity of each of our large towns for a number of the dead equal to the entire population, that the only check to this increasing demand is the desecration of the graves of the poor by the horrible process of "chopping up" their corpses, and that the only sites and soils adapted for interment without danger to the living are precisely those most to be desired for residence and most valuable for agriculture, it will be seen that the abstraction of so large a proportion of the best land becomes a question of grave economic importance, the one solution of which is presented by the more general adoption of cremation.

The objections urged against the practice will not bear serious examination. Few persons indeed would now be found so

superstitious and so ignorant of the economy of nature as to maintain that cremation involves a disbelief in or is incompatible with the resurrection of "the" body (as a certain bishop did not long ago, apparently forgetful of the case of so many holy martyrs), but with the recent improvements in the construction of the furnaces and the arrangements of the chapel and its accessories, elaborated by Professor Gorini, Sir W. Siemens, and others, the process has absolutely nothing that can offend the senses or the feelings, and need not occupy a longer time than can be employed in a solemn service, at the end of which the ashes are restored to the friends, enclosed in an appropriate urn, to be deposited in a niche in the columbarium, or to be taken to the family mausoleum, no small advantage from a sentimental standpoint in these days of migration, when so few can visit the graves of their friends and relatives scattered over the country and the globe.

The fear that cremation would, by precluding subsequent examination, serve to conceal, if not offer an inducement to crime, is exaggerated or groundless. There has not for many years been more than one judicial exhumation to a million deaths; the vegetable alkaloids, by far the most deadly poisons, can rarely, if ever, be discovered under such circumstances; and indeed, cremation might be made to lead to the detection of crime, as it has already done in Italy.

In that country the ordinary medical certificate, which, as we have often seen, gives but a sorry assurance that death has not been due to foul play, suffices for interment; but to sanction the cremation of a body the medical attendant must give one in a special form, having the character of a declaration on oath, and, if proved inaccurate, involving the penalties of the gravest perjury, that from sufficient personal observation he has not a doubt as to the precise nature of the cause of death, and that, under the circumstances, the symptoms could not be attributable to poisoning, intentional or accidental. Failing this assurance, a *post-mortem* examination and, if necessary, an analysis is imperative. It is impossible to say how many murders pass unsuspected under our system of lax certification or burial without any medical certificate whatever.

Summary of Chapter XIV.

Excreta should be utilised wherever possible, but in towns "water-carriage" is indispensable. The sewage is then equal to the water supply and constant: the rainfall inconstant, therefore the two are better separated.

On the **separate system** circular pipe sewers are best; but on the combined egg-shaped as giving greatest average depth and least friction with variable flows: perfect adjustment being impracticable intercepting sewers and storm overflows are often required: the flow should be about $3\frac{1}{2}$ feet per second, not less than $2\frac{1}{2}$, nor more than 4, according to size of channel. When a fall of 1 in 240 cannot be had, anything down to 1 in 480 or 1 in 600 with frequent flushing may do, but it is then better to lay sewers in shorter lengths at good gradients and raise sewage from each to the next by Shone's ejectors all worked by compressed air from a central engine. **Sewers should be freely ventilated**, and gulleys provided to exclude solids.

The **discharge of sewage** more or less crude into running streams is objectionable, into tidal rivers intolerable; and except under special current conditions the sea is not much better: besides the "backwatering" of the sewers by the entrance of rising tides.

No system of sewage treatment equals that by **irrigation** of suitable land, when the effluent may be really pure; when such land is not available the **septic tank**, in which the suspended organic matter is dissolved, followed by nitrification in filters, or far better through grassland, may render it fit for discharge into rivers. **Chemical processes** are very unsatisfactory, the Ferrozone being apparently the best. In land treatment profit earning should not be considered, though under exceptional conditions sewage farms may give a good margin.

Factories, especially woollen mills, paper works, tanneries and others are great sources of **pollution of rivers**, most of which could, however, be avoided by suitable measures. Some rivers in the northern counties are far worse than sewers.

Disposal of the dead.—If the practice of **earth burial** must continue, the coffins should be the most perishable, the soil, light and conducive to rapid disintegration and nitrification, and the graves shallow. In clays there is little decomposition, but a stinking mass remains for many years, even centuries. And bodies interred in any soil six feet or more from the surface may pollute the ground water and wells.

Cremation is in every way to be preferred.

Interment in churches should never be permitted. All sentiment would be satisfied by cenotaphs.

PART IV

HEALTH OF THE PEOPLE

CHAPTER XV

Preventible Disease

In one sense most diseases are preventible, that is, it is more or less in the power of every individual to avoid, and in so far as he can it is his duty to avoid, all known predisposing or exciting causes, such especially as consist in violations of those physiological laws which cannot be disobeyed with impunity.

But the term preventible is by common consent used in a more limited and special sense to denote diseases, the prevention of which rests rather on the state or society than on the individual, who otherwise is liable to fall a victim to external circumstances over which he, as an individual, has little or no control.

They are divided into endemic, infectious, and enthetic; and the infectious again comprise infectious diseases proper, infective, and the transportable miasmata.

Endemic diseases are those which, whether communicable from one person to another or not, are constantly present in a community in consequence of certain unfavourable conditions by which they are surrounded. Such are phthisis induced by damp, deficient ventilation, unhealthy employments, &c., and rheumatism from damp and other climatic conditions.

Malarial diseases comprise the various forms of intermittent and remittent fevers. They are caused not by bacteria, but by parasites of an animal character, hæmatozoa, which, passing their sexual phase, and multiplying in the bodies of certain species of mosquitoes, are introduced by their bites into the blood of human beings, where they pass through a sexual stage, during which they multiply, and enter and destroy the red corpuscles.

Infectious diseases strictly so-called belong to the people, not to the place. They are communicated from one person to another through the air, or by means of infected articles of clothing, &c., called fomites. Such are small-pox, typhus fever, scarlatina, measles, &c.

Infective diseases are also infectious or communicable, but they may be derived from the outer world, or generated in the body of the individual, who thus infects himself, and may then infect others. They include erysipelas, pyæmia, and septicæmia, and tetanus, which however is not communicable.

Transportable miasmata, as defined by Hirsch, are originally due to external local conditions of infected soil, water, &c., but are carried by human intercourse, fomites, polluted water, &c., within certain limits of space and time. Such are cholera, yellow fever, and enteric or typhoid fever.

Enthetic diseases, as hydrophobia, glanders, and syphilis are communicable solely by inoculation.

Rickets is a peculiar disease characterised by irregular and imperfect ossification of the bones. The total amount of earthy

matter need not be much less than in normal bone, but it is differently distributed, and absorbed in one place, while being deposited in others. The heads of the bones are enlarged, dentition and closure of the skull delayed, and the bones are soft and yield to pressure. The chest is altered in shape, especially under the strain of coughing, producing pigeon-breast, while the legs bend under the weight of the body so soon as the child begins to walk, and the pelvis is altered in form by the weight of the trunk in sitting.

The causes are mal-nutrition before or after birth, improper food of any kind, and above all, the practice of artificial feeding with so-called "foods," *i.e.* starchy and farinaceous matters, which the infant organs cannot assimilate. There is no evidence, clinical or experimental, in support of the view so generally held, and given in many books, that a deficiency of earthy matter in the food is the cause, or even a cause of rickets.

To avert it the infant should be fed on milk alone, its natural food ; if the mother's milk be insufficient it should be supplemented by that of the cow ; with very young infants the best condensed milk is more easily digested than fresh cow's milk ; and when the disease has been developed, milk, cream, eggs, and cod-liver oil should be given, with plenty of fresh air, and everything that can conduce to the improvement of the digestion and general health.

Scurvy follows deprivation of fresh food, and especially of fresh vegetables. It is most frequent among the crews of badly victualled ships and prisons. It is marked by spongy gums, painful inflammation of the bones, abscesses and ulcers, and tendency to hæmorrhage. It sometimes accompanies rickets in infants. See the section on Dietetics.

Consumption or **Phthisis** is a general expression, including a number of pathological conditions differing in their causes and course, but agreeing in the presence of a slow inflammatory process involving destruction of the substance of the lung. In some the starting point is a chronic catarrh, the products of which the organism is unable to throw off, and which therefore act as foreign bodies, setting up irritation in the air vesicles. In others the same effects are produced by the entrance of dust, mineral or organic, and in most cases there is either from the first, or as a secondary and superimposed condition, a peculiar process termed tuberculosis, affecting

mainly the lymphatic structures, and caused by the invasion of the tissues by a specific organism.

Everything that lowers the resisting and recuperative power acts as a predisposing cause, repeated catarrhs, dampness of the subsoil, deficient supply of pure air, especially the breathing of air rendered impure by the products of respiration and combustion, and the inhalation of dust and irritating particles of all kinds.

The beneficial consequences of drying the subsoil were first noticed by Mr. Middleton in the enormous reduction of the mortality from phthisis at Salisbury, after the removal of the ground water by drainage, and were worked out by Sir G. Buchanan in a study of the relation between phthisis and the nature of the subsoil and efficiency of the drainage. For example, he found the death-rate from phthisis in Kent, Surrey, and Sussex, to be lowest on the Thanet and other sands, and on the chalk, and highest on the clays, especially those of the Weald; and the reduction that followed thorough subsoil drainage in towns, was in Salisbury from 44 to 22 per 10,000; in Macclesfield from 51 to 35; in Ely 31 to 16, and so on.

All such statistics, however, are more or less falsified by the fact that they do not distinguish between the catarrhal phthisis, which is directly induced by cold and damp, and the tubercular form, which is properly a specific infectious disease, wholly independent in itself of such conditions, although phthisical persons are specially susceptible of tubercular infection.

A large proportion, perhaps the majority of consumptives are not, at any rate for some time, tuberculous; and tuberculosis is by no means exclusively or mainly a disease of the lungs, the organs attacked being mostly determined by the point at which the bacilli obtain access to the system. Thus in infants it is the glands of the intestine, pointing to milk as the vehicle, in adults those of the neck, the larynx or the lungs, the bacilli being generally inhaled. In other cases the bones or the serous membranes of

the chest and abdomen, and, mostly in children, those of the brain through the thoracic lymphatics. But the lungs are generally involved sooner or later for the simple reason that the whole of the blood passes through them, and no other organ is so richly supplied with blood vessels and lymphatics. In pulmonary tuberculosis the intestines are subsequently implicated from the common habit of swallowing the sputa, a practice that cannot be too strongly condemned.

The discovery of the tubercle bacillus by Koch in 1881, by which Volkmann was enabled to bring under the category of tuberculous diseases a host of hitherto unclassified affections of the bones, glands, skin, &c., the success that has attended its cultivation, and inoculations of animals therewith, has placed the infectious character of the disease beyond the possibility of further question.

The frequency of the disease among cows and the presence of the bacilli in their milk point to its use as one of the causes of the prevalence of tuberculosis especially among children, and to the expediency of boiling all milk not known to be the product of animals in perfect health; while to direct infection, and not to "rebreathed" air, is due the prevalence of pulmonary tubercle among persons working in ill-ventilated and crowded rooms.

Its transmission from parents to offspring has been proved to occur though very rarely; it is also capable of being communicated by means of the mother's milk, but in the vast majority of cases heredity so called means no more than inherited feebleness of constitution and susceptibility to infection that may be overcome by removal in childhood to more favourable conditions of climate, locality, dwelling, clothing, and food.

The benefits of a life in the open air are strikingly illustrated by the remarkable freedom from consumption and other respiratory diseases enjoyed by fishermen and agricultural labourers, subject though they be to every kind of hardship and exposure. The climates whether warm or cold in which the greatest proportion of time can be passed in the open air are those where there is the least amount of consumption; thus our troops in Canada suffer far less than those in the West Indies, and the Engadin is at least as good for invalids as Algiers for Egypt.

Scrofula is a general term applied to the accumulation in the glands, and mucous and serous membranes of the products of inflammation, degenerated cells, &c., which the organism is too feeble to throw off or absorb. It is therefore the result and indication of a generally low state of nutrition. But most "scrofulous" glands are really tubercular.

SPECIFIC DISEASES

These, which include the majority of the preventible diseases, are so called because they are produced, not by any disturbance of the functions of nutrition, circulation, &c., or by physical agencies, as heat or cold, but result from the entrance into the body of minute parasitic organisms belonging to the class of fungi, which multiplying by division are distinguished as *schizomycetes*. They are collectively known as *bacteria*, and the several forms as *bacilli* (rods), *microccocci* (minute spherical bodies), *streptococci* (chains of beads), *spirilla* (spiral bodies), &c.

Bacteria are the active causes not only of diseases, but of all putrefactive, fermentive and like changes, by which dead organic matter is reduced to its inorganic constituents and fitted to become the food of plants. They are thus *pathogenetic*, as causative of disease, or *saprophytic*, as the agents in putrefaction, though many of the latter may, if ingested or inoculated, set up forms of disease, and others have a double existence.

Bacteria in the process of their development generate in and from the fluids in which they grow, various chemical products, some of which (toxins) are the immediate causes of the phenomena of the disease, and others (antitoxins) may be formed which neutralise the toxins, or which destroy the bacteria, thus terminating the morbid process, and rendering the individual for a longer or shorter period insusceptible to subsequent infection with that particular disease.

Obligate parasites are those bacteria which, so far as we know, are incapable of developing and multiplying, save in the animal body or in artificial media resembling it in essential conditions. *Facultative* are such as have an independent external existence, perpetuating themselves in the soil, water, &c., whence they by chance gain access to the bodies of man or beast, and may or may not be transmissible from one individual to another.

Diseases caused by obligate parasites are thus necessarily communicable, but those due to facultative parasites may or may not be so.

To put the matter in popular language, we may say that every case of disease due to the former has been derived directly or indirectly from a previous case, and the disease would never appear in an isolated community from which every infected person and thing was excluded ; whereas those caused by facultative parasites may at any time break out when the microbes present in the soil or water happen to be swallowed inhaled or inoculated, and may spread by means of contagion to other individuals. The disease in the first instance might be said to arise *de novo*, there having been no previous cases, but not *de nihilo* like catarrhs, inflammations, &c., which have no *material* causes.

Obligate parasites, however, though incapable of growing out of the living animal body, may when dried at ordinary temperatures, retain a dormant vitality for a longer or shorter time, ready to resume an active life when brought under appropriate conditions. This power, which is not unknown even among the higher forms of animal life, is possessed in far greater degree by the spores, which some of them in common with other fungi produce in the form of minute spherical bodies left behind when the bacillus itself perishes, precisely as in the case of the fresh water sponges, and bearing a remote analogy with the seeds of plants and the eggs of animals. It is thus that the infection of fevers and even of tuberculosis is long retained by clothing, &c., and in the dust adhering to the floors and walls of rooms.

Bacteria like all living things may be killed, and on this is based the whole theory of disinfection. Some are more resistant than others, and the spores are always more so than the mycelium, as the growing form is called, but none can long withstand a temperature of 100° C. (212° F.) especially if moist but cold, even that of liquid air, – 190° C., as Macfadyen has shown is powerless. A host of chemical re-agents possess more or less

germicidal power. The first rank must be awarded to corrosive sublimate of which a solution of 1 part in 1000 of water is sufficient for all purposes. For walls and ceilings quicklime is equally efficient in the form of lime (not white) washing.

Little inferior to sublimate as a germicide, and safer for general and domestic use is formaldehyde, 1 part in 800, non-corrosive, and volatile.

Carbolic acid, sulphurous acid, chlorine, zinc chloride, and iron sulphate are all, in the presence of water, fairly successful as germicides, but far inferior in every respect to the sublimate.

Permanganates of potassium and sodium (Condy's fluid), oxidize and sweeten putrescent matter, but are not powerful germicides, or antiseptics; and the essential or volatile oils of the Terebene series ("Sanitas," thymol, &c.) are non-poisonous, and appear to be active germicides as well as oxidizers.

Far too great importance is attached by some to oxidation as a means of disinfection, for living bacteria cannot be oxidised in the same way as dead organic matter. Some indeed are found to flourish most in the absence of air, and are thence called anaërobes, while others require the presence of oxygen and are known as aërobes. Some, as the cholera bacillus, can adapt themselves to an aërobic or an anaërobic condition; in the former they are very resistant, but have little pathogenic energy: in the latter they are highly virulent, but feebly resistant, being destroyed by the acid of the healthy stomach.

Even light is inimical or fatal to the development of some, as that of typhoid, while the bacillus of diphtheria is wholly unaffected by it, a fact of considerable importance in explaining the propagation of these diseases respectively.

Again some thrive in putrid organic matter, notably those of the so-called filth diseases, enteric [typhoid], cholera, diphtheria, and septicæmia, whereas others, as those of tuberculosis, rapidly perish in the presence of septic processes and suppuration of abscesses. On the other hand the bacillus of tetanus has little, and its spores no power whatever of developing in healthy flesh, requiring for the success of the inoculation the presence of some unhealthy discharge, foul pus, or putrescent organic matter, or even of certain acids, as lactic and butyric, &c.

I have assumed that all specific and communicable diseases are caused by microbes or bacteria; it is true

that in several the specific microbe is as yet undiscovered, and that in others its specific character is not yet experimentally demonstrated, since for absolute proof a number of conditions are required, some of which may be from the nature of the case unattainable. Theoretically the microbe must be present in all cases of the disease and under no other circumstances; it must be capable of pure cultivation in artificial media, and its inoculation into animals must be followed by the development of all the characteristic phenomena of the disease. But appropriate artificial media may not at present be discovered, and a human disease may not be communicable to the lower animals, while experiments on the human subjects are obviously inadmissible.

The complete demonstration has been attained in tuberculosis diphtheria, tetanus, erysipelas, septicæmia, anthrax, and a few others; but since the poison in all is capable of indefinite multiplication in the body, and of being destroyed out of it by the means known to be fatal to the lower forms of life, it must be a living and not a chemical or inanimate agent: while the character and sequence of the phenomena are so constant and so strictly parallel in all these diseases that the causes of each must be *ejusdem generis*, and what is proved of some may be safely assumed of the rest.

In a pamphlet on the "Natural History of Specific Diseases" published in 1889, I attempted a rational and strictly scientific classification, proposing the terms *Intracorporeal* and *Extracorporeal* for the two great classes of microbes, viz., those which are wholly and those which are only accidentally or occasionally parasitic, in nearly the same sense as the awkward and un-English expressions *obligate* and *facultative* have since been used; further subdividing these classes into *non-recurrent* and *recurrent*, according as one attack does or does not confer subsequent immunity from infection; into those of definite, indefinite or persistent duration; and of universal distribution or confined to certain climates.

The classification I have suggested is shown in the following tabular arrangement :—

SPECIFIC DISEASES.

I.—CONTAGIA.

A. Intracorporal.

a. Of a definite duration,

α. *Non-recurring.*
Variola and Varicella.
Typhus and Plague.
Scarlatina, Rubella, and Measles.
Whooping Cough. Mumps.

β. *Recurring.*
Pneumonia, Influenza, Dengue. Cerebrospinal Meningitis ["Nototonic Fever"].

b. Of indefinite duration.

α. *Non-recurring.* Syphilis.

β. *Recurring.* Gonorrhœa. Chancre.

γ. *Persistent.*
Tuberculosis with Leprosy and Lupus.

B. Autochthonous.

(Generally common to man and animals, of indefinite duration and Recurring.)

Some forms of Tonsillitis, Diarrhœa, Pneumonia, Acute Rheumatism, &c.

C. Extracorporeal.

(including, together with some others, the Communicable Miasmata of Hirsch.)

a. Territorial.

α. *Non-recurring.*
Yellow Fever.

β. *Recurring.*
Cholera.

b. Universal.

α. *Non-recurring.*
Enteric Fever.

β. *Recurring.*
Loefflerian and Streptococcal Diphtheria.
Erysipelas, Septicæmia, and Tetanus. Ophthalmia.
Some forms of Diarrhœa and Dysentery.

γ. *Relapsing.*
Relapsing Fever.

Although the whole of these are properly human diseases, rats are highly susceptible to plague, and dogs and swine in a lesser degree. Ruminants and rodents, when domesticated, are very prone to tuberculosis. Those contagia under the heads, B, and C, b, β are for the most part common to some other animals, horses being specially prone to tetanus and cerebrospinal fever, and cats to diphtheria, while plague is believed by many to be originally or properly a disease of the rat.

D. Zootic Contagia

(Communicable to Man.)

a. Without Change of Characters.
Anthrax. Glanders. Plague (?)
Foot-and-Mouth Disease.

b. In a Modified form.
Rabies as Hydrophobia.

II.—HÆMATOZOIC.

(Non-communicable.)

Paludal or Intermittent and Remittent Fevers.

III.—MYCETOSES.

a. Ectophyta.
α. Proper to Man.
Pellagra. Madura Foot.
Delhi, Biskra, Aleppo, or Pendja Boil.
β. Proper to Animals.
(But communicable to Man.)
Actinomycosis.

b. Ectophyta.
Tinea tonsurans and Decalvans.
Sycosis. Favus. Chloasma. Thrush.

The term "Autochthonous" is new and calls for explanation. By it I wish to indicate diseases due to microbes which, though proved experimentally to be the specific cause of diseases, are frequently found in healthy persons, and indeed are generally present, but under conditions as chills, fatigue and exhausting illness tending to depress the power of resistance, undergo enormous multiplication and assume a pathogenic character.

To the Italian and especially the Roman physicians we owe the demonstration of the causation of tetanus (the "lockjaw" following some wounds) in a microbe present in the soil. The special tendency of wounds of the hand and foot to be followed by

tetanus is owing to the fact that these are the most apt to be attended by the introduction of dirt, while the rarity of tetanus notwithstanding the ubiquity of the bacillus is explained by Kitasato by the complexity of the conditions required for the growth of the bacilli or their spores, which does not take place in clean wounds in healthy tissues, and the disease is not spread by ordinary contagion.

Hitherto physicians have described traumatic and idiopathic forms of both erysipelas and tetanus, that is, cases following wounds and cases occurring spontaneously, but we can no longer admit a double origin. In each disease the wound may be a mere abrasion or chap of the skin, so trifling as to have escaped notice, but providing a means of ingress for the spores everywhere present in the outer world. The fearful spread of erysipelas once admitted into surgical wards of hospitals is well known.

The so-called idiopathic form almost always starts from the lips, nose or eyes, parts specially liable to minute breaches of the surface which inquiry will always elicit.

The **malarial fevers** differ from the foregoing in being confined to particular localities, not communicable from man to man : and attacking only persons resident in or passing through the infected district. They are known as malarial diseases or paludal fevers, and popularly as agues, Roman fever, jungle fevers, and Black water fever.

They set in with rigors, followed by the so-called cold, hot, and sweating stages, when after an interval in which the temperature falls, the same cycle of phenomena is repeated at regular periods. They were formerly distinguished by medical men into intermittent and remittent fevers, according as the paroxysms alternated with intervals of entire freedom from fever, or with short remissions only of its intensity. In the former there is a well marked "cold stage" followed by a hot stage, and then an interval of a certain length. If the paroxysms return daily it was called quotidian ague, if every second or third day tertian or quartan. In the remittent fever there is no such pause, and the cold stage is, after the first time, perhaps almost unrecognisable ; a succession of remissions and exacerbations following closely on one another. But though the tropical and other types are associated with different parasites, there is no essential difference between intermittent and remittent fevers, the form assumed depending on the intensity of the poison, and the accidents of climate and season. Generally

speaking, the remittents are confined to the tropics, the intermittents prevailing in more temperate zones; while in Italy, Algiers, and Egypt, the type varies with the season, and everywhere remittents assume during convalescence the intermittent form.

This periodicity, which continues, though with decreasing intensity and regularity, for some time after removal from the malarial influence, might at first sight seem inconsistent with a parasitic causation, were it not that in Relapsing Fever, which is contagious, though like the intermittent fevers confined to certain countries and races, a microbe, the *spirillum* (or *spirochæte*) *Obermeieri* has been repeatedly observed, appearing and disappearing with the alternation of the attacks.

There is now no doubt that the specific organisms first found in the blood by Laveran and by him named *Plasmodia*, of which three or four varieties are distinguishable, are the actual cause of the disease. Apparently, the necessary conditions for the generation of malarial fevers are—(1) an excess of organic matter in the soil above what the vegetation is capable of assimilating; (2) a certain temperature; and (3) a certain amount of moisture. Elevation has only a secondary influence; so far as the requisite conditions are most frequently met with in low lands, so is malaria; but it may be found in valleys at altitudes of several thousand feet, the other conditions being present. In hot countries it prevails all the year round, in temperate ones chiefly or solely in the summer and autumn, and in Finland, where every condition other than temperature exists, only in unusually warm seasons. Complete dessication of the ground and entire submersion alike arrest it, but in the mid period it appears with great intensity in the deltas of large rivers, as the Nile or Danube. It is carried through the air, especially by night, and in the direction of the prevailing winds, but does not ascend to any height. Its progress may be arrested by an expanse of water, especially if salt, by a range of hills, and even by a belt of trees.

It is commonly supposed that the negro races enjoy immunity, but it has been found in H. M. Navy that when they are compelled to use soap and water for ablution instead of anointing their skins with grease, they become as susceptible to malaria as their white comrades. All these "conditions" receive a new interpretation in the light of recent investigation; *anopheles*, like other gnats, are not met with in arctic, or during winter in temperate climates, though abounding throughout the year in tropical and subtropical. They breed in ponds and stagnant waters, not too salt or putrid, they haunt shady places by day, coming out at night but not flying very high above the ground. All these conditions may, however, concur, without giving rise to

malarial fevers, as in Canada where during the autumn gnats of various kinds abound, but those of the genus *anopheles* are absent. In fact, though the parasite is the actual cause, the presence of its two hosts, *anopheles* and men together, is necessary to its existence. Thus Sir W. MacGregor and his *healthy* party did not suffer from the bites of the swarming *anopheles* more than from those of common gnats, in the *uninhabited* mangrove swamps on the northern shores of New Guinea; and fevers were unknown in Mauritius, except in the persons of coolies from India, until 1867, when the *anopheles* was accidentally introduced, and transferred the parasites from the immigrant to the native population, rendering the disease endemic.

The attacks may be prevented, aborted, or cured by large doses, or better, the subcutaneous injection of smaller doses of the most soluble salts, of quinine, the acid hydrochloride being the best; but in removal to a locality free from the conditions favourable to malaria lies the only chance of permanent restoration to health. But in drainage, with the obliteration of ponds and ditches and permanent lowering of the ground water, and in cultivation of the soil, we have a sure though slow means of causing its disappearance, as has been very nearly accomplished in this country.

The more speedy and heroic procedure of carrying on a crusade for the extermination of the *anopheles*, by covering all the waters containing their larvæ with a film of petroleum, and destroying the insects in houses by fumigation, is not so Utopian as it might appear, having been completely achieved in the Italian convict island of Asinari, where no new cases have appeared last year, against 100 in that preceding.

Ways and Means of Infection

Infectious diseases may be communicated by direct inoculation, by personal contact, or by sojourn in infected localities; the microbes or their spores, retaining their vitality out of the body or other suitable habitat for longer or shorter periods, may be carried by such vehicles as air, water, fomites, or food to greater or less distances, and gain access to the organisms of susceptible individuals by the respiratory or alimentary passages, by wounds or abrasions of the cutaneous surfaces, or by absorption

through mucous membranes without any breach of their continuity.

These may be distinguished as (1) Inoculation, (2) Absorption, (3) Inhalation, and (4) Ingestion.

Some diseases are communicated, or rather received by one, and others by two or more of these modes, in the latter case either with equal frequency, or usually by one, and only exceptionally by other ways. Inoculation and absorption are closely allied, a poison certainly introduced by inoculation being probably also capable of absorption by an unbroken mucous surface, and conceivably, though improbably, by the skin.

1. **Inoculation.**—Exclusively or commonly thus received are the zootic contagia, rabies (as hydrophobia), anthrax and glanders; the extracorporeal contagia of tetanus, erysipelas, and septicæmia; and, though rarely, small-pox (and its modification cow-pox); while an abrasion greatly facilitates the infection of syphilis, chancre, and gonorrhœa. Inoculation by means of mosquito bites is the chief if not the only means by which the hæmatozoa of malarial and yellow fevers are spread.

Under exceptional circumstances others may be inoculated, as diphtheria and tuberculosis.

2. **Absorption** by mucous surfaces is the rule with venereal diseases, and also with septicæmia in the puerperal form. Ophthalmia is the infection of the conjunctiva by absorption of the purulent discharge from other cases, or by any infectious purulent secretion. Glanders may be thus communicated to man, and diphtheria is more probably received by absorption than by inhalation, the seat of infection being the naso-pharyngeal and laryngeal mucous surfaces where the microbes are arrested, and not the pulmonary or even bronchial passages, except secondarily. Erysipelas, when commencing from the conjunctiva, is probably due to absorption. Measles is easily absorbed from pocket-handkerchiefs, &c., as are scarlatina and whooping cough, &c.

3. **Inhalation** is unquestionably by far the most frequent means of communication of the whole of the non-recurring intracorporeal contagia, viz., variola and varicella, typhus, scarlatina, rubella and measles, whooping cough and mumps, as well as of plague and of tuberculosis in the adult.

Diphtheria may be placed here with the qualification expressed under the preceding head.

Enteric fever is frequently thus spread in camps in hot countries through the dried and pulverised excreta inhaled or swallowed with the dust, and to a less extent in hospital wards and laundries from the soiled linen and bedding of the sick; dysentery and some forms of diarrhœa, are probably, and cholera, possibly though very rarely, thus admitted into the organism.

Lastly, the contagious forms of pneumonia and cerebrospinal meningitis,[1] when epidemic, must, it would seem, be thus communicated.

4. **Ingestion.**—This is certainly the rule with cholera and enteric fever, and probably so with dysentry, and some forms of diarrhœa. Tuberculosis can be communicated by the milk of infected animals, and much infantile tuberculosis, *i.e.*, mesenteric tubercle, is doubtless thus induced. The infectious character of the milk of cows suffering from foot-and-mouth disease has been proved experimentally,[2] and diphtheria has frequently been shown to have been conveyed by water and milk.

The occurrence of undoubted epidemics of "milk scarlatina" renders it probable that other diseases may be spread by this means, though it has not been proved even of measles.

[1] A clear account of the spread of this disease by intercourse and by fomites, showing incubation periods, &c., is given by Kohlmann, *Berl. Klin. Wochensch.*, 1889, No. 17.

[2] See (Art.) "Maulsucht," in Eulenburg's *Handbuch, d. Gesundheitswesens.*

The raw or imperfectly cooked flesh of tuberculous animals, and that of those affected with other diseases, may be a vehicle of communication.

This belongs, however, to the next division of the subject, viz., the means by which infection is carried before gaining access to absorbent surfaces by being brought in contact with them.

The Vehicles or Proximate Media of Contagion are air, water, and fomites, and most communicable contagia are carried by two at least of these.

Typhus is communicated by fomites and by aerial diffusion, though not for any considerable distance. Highly contagious within a limited area, the contagium is greatly enfeebled by dilution or diffusion—in other words, by ventilation of the ward—and rarely, if ever, spreads through the outer atmosphere to neighbouring houses.

Scarlatina.—In the early stages of this disease the infection resides chiefly in the breath and mucous secretion of the naso-pharyngeal passages. It is communicable in this way to persons in close personal contact even in the pre-eruptive stage, a child in the same bed succumbing while others in the room escape. Later on it is given off from the skin, and is contained in the urine, while during convalescence, so long as desquamation lasts, the epithelium cast off from the body, and for a still longer period the breath, are active vehicles of infection. But the contagion is not carried aerially to any great distance, and it is comparatively easy in a well-arranged house by proper precautions to obviate its extension to the occupants of other rooms. The naso-pharyngeal secretions are so virulent that pocket-handkerchiefs should never be used—soft linen or cotton rags being substituted, and immediately burnt. In schools, &c., it is most often propagated by the shedding of the epithelium of children allowed to mix with others before the desquamation has entirely ceased. Fomites may retain the contagion for

months, and many cases the origin of which appears unaccountable might be traced to the workshops or rooms of tailors, dressmakers, &c., several such having come under my own observation.

Measles.—Here the contagion is contained almost exclusively in the naso-pharyngeal mucus and breath. It loses little by diffusion, and the isolation of the disease is difficult in the extreme. It is highly infectious in the pre-eruptive stage, when it is most frequently propagated, it being impossible to distinguish the symptoms from those of a common catarrh ; and attempts at isolation, after its nature has been recognised, are almost invariably too late. The only means of arresting an epidemic in boarding-schools is the isolation not only of the actual cases, but of those that have been in contact with the primary case at any time from the first symptoms of catarrh. All children who have been, during the week preceding the eruption, in the same dormitory or even classroom, should be considered as suspects and quarantined for a fortnight, any who meanwhile show the least symptoms of catarrh being immediately transferred to the infirmary.

The contagion can be conveyed by fomites, especially handkerchiefs and pillows ; but it does not ordinarily retain its vitality long, and disinfection, beyond washing in hot water, is practically unnecessary.

I may add, however, that measles is occasionally propagated, like scarlatina, during convalescence, and after the eruption has disappeared.

The same remarks apply to **Rubella**, **Whooping Cough** and **Mumps**, which are constantly spread among girls and women by kissing, but may be carried by third parties.

Small-pox.—The propagation of small-pox is a question of the utmost practical importance, but one on which there is the greatest diversity of opinion.

It is infectious from the commencement, but the infec-

tion gains in intensity with the progress of the eruption, up to and inclusive of the process of scabbing. The cocci are contained in the mucous secretions and in the puriform contents of the pustules. But they are given off most abundantly after these have undergone desiccation, diffusing themselves as a fine dust far and wide. The strong vitality of the microbes, and the retention of their activity unimpaired by prolonged desiccation, render the propagation of small-pox by fomites more general than that of perhaps any other disease.

But the question which at present divides the sanitary world is that of the so called distal aerial diffusion of small-pox, the practical importance of which is its bearing on the alleged danger of small-pox hospitals to the surrounding populations.[1]

The chief exponent of the hypothesis of distal aerial diffusion of small-pox is Mr. Power, who brought it prominently before the public in his report, in 1881, on the Fulham Hospital. His method of procedure, which has been followed by others, is to draw a series of concentric circles around a hospital at distances of a quarter, half, and one mile, and to note the relative incidence of small-pox within each of the zones thus described. I freely admit that in the cases, *e.g.*, of the Fulham, Homerton, Stockwell, and other hospitals of the Metropolitan Asylums Board, the morbidity and mortality per 1000 of the population has been double in the inner circle what it has been in the next zone, and tenfold that of the outer ring, and I do not deny that the hospitals have been the cause of much of this prevalence of small-pox in their vicinity: but I do not believe that it has been through aerial diffusion. Dr. Dudfield, indeed, was able to trace a large proportion of the cases in South Kensington to importation from other parts of the Metropolis, and Mr. Makuna, in a laborious investigation by house-to-house visitation (*Med. Times*, 1884), collected a mass of facts

[1] See *Trans. of Soc. Med. Off. Health*, 1884—5.

completely subversive of Mr. Power's conclusions; but though the incidence might to some extent be consequent on the presence of the hospital in the locality, I maintain that the disease was spread wholly by personal intercourse. The laxity of the regulations controlling the access of tradesmen and others to the premises; the freedom allowed to nurses and ward servants; and, above all, the visits of the patients' friends, many of whom were afterwards themselves admitted: in a word, the glaring errors in construction and administration were more than enough to account for any amount of infection in the locality. Mr. Power referred every single case occurring in each zone to the influence of the hospital, regardless of the fact that a number of small-pox patients were permitted to remain at their own homes, acting as foci of infection—twenty, thirty, and in one instance reported by Dr. Tripe, fifty cases having been traced to a single patient in some densely crowded court or alley. It is remarkable that such an influence has never been suspected in the case of hospitals in provincial towns—that is, of hospitals properly so-called. Among seventy such, the outward spread of small-pox was established in the case of two only, which being houses in a street, were utterly unfitted for the purpose. At Nottingham, Dr. Seaton could not discover a single instance of infection from the hospital, even among the workpeople of a factory, the windows of which actually overlooked the hospital yard, though many were unvaccinated and none revaccinated.

At Hampstead, as Dr. Bridges stated before the Commissioners, the spread of the disease ceased so soon as visits to the hospitals were prohibited. But the crucial test is to be found in the story of the hospital at Deptford, which abuts upon a railway. Here the "spot maps," on which Mr. Power and the rest rely, show the usual distribution of small-pox, increasing as one approaches the hospital—but *on one side only;* the streets

on the other—*i.e.*, beyond the railway—enjoying complete immunity. The explanation is obvious. The railway, which as an open space would rather have facilitated aerial diffusion, presented an absolutely insuperable barrier to human intercourse. Mr. Power believes also in the intensification of the poison by the aggregation of large numbers of patients in one building, and it was in consequence of his representations that the Asylums Board determined in the last epidemic on limiting the number in each hospital to twenty-five or thirty. The results, however, were the very reverse of what they expected, for the prevalence of small-pox in Hampstead when the number of patients was under thirty was four times as great as when there were 600! To me this is not surprising, though it is utterly incompatible with the notion of intensification. On previous occasions the patients were detained until they could be discharged with perfect safety; but under the restrictions above mentioned, convalescents still in the most infectious period—the stage of desiccation and desquamation—were removed to the camp hospitals; while milder, but not less dangerous cases, were sent away after an hour's detention, thus multiplying the transport of infectious patients through the streets, with all the attendant risks, at least fourfold.

Tuberculosis being a bacterial disease communicable by inoculation, the possibility of its being communicated by other means cannot be ignored or denied, however difficult of verification in consequence of the slow progress of the disease and the obscurity attending its development. The frequency with which several members of a family succumb in succession is suggestive of infection, and would be presumptive were it not explicable by a hereditary tendency or susceptibility to [infection with] the disease, and the fact of their having long been exposed to like surroundings. Dr. Payne has collected numerous cases of the infection of whole

families free from hereditary taint after residing in rooms or houses previously occupied by persons suffering from tuberculosis. And though it has been asserted that nurses in consumption hospitals do not afford confirmation of the hypothesis of its communicability, the voluminous statistical evidence collected by Dr. Georg Cornet proves the contrary to be the fact.[1]

Assuming the communicability of tuberculosis, suspicion naturally falls on the breath as a vehicle of infection, but all observers have as yet failed to detect the bacilli, even when they swarmed in the expectoration. The fact is that they are confined to the sputa, are so heavy as to sink in water, and are, therefore, incapable of aerial diffusion so long as the medium containing them is moist; but if the sputa be allowed to dry, the spores are easily raised by draughts and diffused as dust. This occurs when the sputa are received in a handkerchief or cast on the floor, but not when the use of spittoons is strictly enforced, as in well-conducted hospitals. In this dusty form they are inhaled, gaining access to the lung tissue by some presumably weak spot, though in the majority of cases they are arrested in the nasal or oral passages, where they mostly perish. But that this does not always happen is evident from the frequent occurrence of tubercular (so-called scrofulous) glands in the neck, to which the bacilli can gain access only by means of the lymphatic vessels from the tonsils, pharynx, &c., and it is a matter of common observation that the subjects of tuberculous glands have been previously prone to "sore or weak throats." Hirt, in his laborious researches into the health of operatives of all classes, came to the conclusion that while those employed in dusty employments carried on in the open air, or alone, suffered from every form of "pneumokoniasis," or bronchial and pulmonary irritation, phthisis, bronchiec-

[1] *Die Sterblichkeitsverhältnissee in der Krankenpflegeorden*, von Dr. G. Cornet; als *Zeitschrift für Hygiene* Bd. VI., 1889.

tasis, &c., they showed no greater tendency to tuberculosis than the general population ; whereas workmen employed in crowded and ill-ventilated factories and workshops—even, as in tailors' shops and printing-houses, where there was little or no dust—were especially subject to tubercular disease, since one or two tuberculous individuals expectorating on the floor would suffice to infect all who were naturally susceptible or were rendered less able to resist infection by their insanitary surroundings.[1] Thus Dr. Dujardin-Beaumetz has recorded the deaths from tuberculosis, within eleven years, of fourteen out of twenty-two clerks employed in a badly ventilated office in Paris, the floor of which, rough and ill-laid, was swept in the morning, the room being often filled with dust, when the men entered ; but no more cases occurred after the boards were planed, waxed and cleaned with damp cloths.

The most frequent vehicle of tubercular infection is, therefore, the inhalation of dust containing the desiccated spores of the tubercle bacillus.

That the milk of cows suffering from tubercular disease may, if the mammary glands be involved, contain the bacilli, and in this we have the explanation of the tendency shown by tuberculosis in infancy to attack the mesenteric glands ; and the increasing mortality in early childhood, while it is decreasing at all other ages, is doubtless connected with the general substitution of the bottle for the breast. Tubercular meningitis, vertebral tuberculosis, and hip joint disease, are secondary conditions due to absorption of the bacilli by the lymphatics of the abdomen. The supervention of peritoneal on pulmonary tuberculosis in adults results from the habit of swallowing the sputa.

Since tubercle bacilli or their spores may retain their vitality in the moist or dry state for long periods

[1] L. Hirt, "Die Staubinhalationskrankheiten," *Deutsch. Viertelj. f. Gesundheitspflege*, V. 280 ; and Birch-Hirschfeld, Art. "Pneumokoniosis," in Eulenburg's *Handb. d. Gesundheitswesens.*

out of the body, I would suggest that the loss of favour from which each vaunted health resort for consumptives suffers in its turn may find its explanation, not in the freaks of fashion, but in their becoming in course of time infected localities, a fate which can never befall that which alone sustains its reputation—the ocean.

Cholera.—Only the ignorant and excitable populace of Southern Europe and the Levant still look on cholera as infectious in the same sense as the plague. A number of Indian medical officers even maintain that its migrations are independent of human intercourse, and conditioned solely by atmospheric and telluric—in other words, by unknown, influences. These notions find favour with the Government, for the simple reason that they assume the uselessness of all interference with commerce, or, indeed, of any action whatever. But other authorities, of equal or greater judgment and experience, are convinced that cholera, endemic within a limited area in Lower Bengal, is from time to time carried in the routes of trade, armies, and above all, of pilgrimages and fairs, under favourable climatic and seasonal conditions. Its sudden appearance in districts where it has been unknown for several years, on which the anti-contagionists (so-called) insist, is easily explained on my theory of its extracorporeal origin. I have from time to time discussed the question in all its bearings in the leaders of the *Medical Times and Gaz.* and *Brit. Med. Journ.*, and will assume here as proven that the vehicles are soil and water, and fomites fouled by the excreta of choleraic persons. The occurrence of sporadic cases and of localised and isolated epidemics, as that at Altenburg, are due to the movements of individuals already suffering, perhaps but slightly, infecting the soil and water of the places where they have sojourned. Being extra-corporeal and in its home limited by climatic and other circumstances, it is greatly controlled in its movements by corresponding conditions, sparing localities where the general sanitary surround-

ings are good, and ravaging those where the soil and water are polluted.

The preponderating influence of the water supply as a factor in the spread of cholera was conclusively demonstrated in the last outbreak at Hamburg, a city the general sanitary conditions of which are above the average. The only blot on its character was the water supply, and no sooner was this specifically polluted than the disease broke out simultaneously over the whole district, while the rest of Germany, though exposed to invasion on all sides, was kept almost entirely free. The evidence afforded by Hamburg on the one hand and by Rome and Seville on the other shows that, with a water supply beyond reach of contamination, general insanitary conditions will not originate and scarcely even conduce to the spread of the disease ; while, should the public supply become the vehicle of the poison, the best conditions are unavailing against it. Herein lies the great danger of rivers as sources of water supply, and above all of tidal streams in which, though the intake be above the town, each rise of the tide reverses the current. Wells may be more generally exposed to pollution, but the influence of each is limited ; whereas a polluted public service infects an entire population simultaneously, however good their sanitary and social conditions in other respects. At Hamburg the water was infected by Russian emigrants camped on the river-side above the intake, but Altona, though drawing its supply also from the Elbe, escaped owing to the greater efficiency of its filtration.

The infection may be transported in formites, as clothing, sacs, &c., actually soiled with the cholera excreta, but is not carried by the air ; whence it rarely happens that the attendants in a well-conducted hospital are attacked : if they are, it is no doubt due to some personal neglect, by which the microbes contained in the copious fluid evacuations have become attached to the hands or utensils and have thus gained access to the alimentary canal ; so too the sudden outbreaks at Yankton,[1] Dakota, among the Russian immigrants, and on board the *Swanton* and *New York*,[2] following the opening of chests containing

[1] *Report of the Cholera Epidemic of* 1873 *in the United States*, p. 462.
[2] *Id. loco*, p 608.

infected clothing, may be accounted for, through "eating with unwashen hands."

In the lower basin of the Ganges, and other districts where cholera is endemic, it is rarely quite absent, sporadic cases occurring at all seasons ; but it annually, on the return of certain meteorological conditions, assumes the character of an epidemic.

In a wider range of the earth's surface it occurs, though less regularly, as an epidemic under favourable meteorological conditions, such outbreaks being sometimes traceable to direct importation from its home, at other times not directly so, but occurring in localities where it has been observed to prevail in former seasons. Thus troops in India are now advised to avoid halting on the sites of old camps.

In temperate regions its visits may always be traced to India, along the great routes of human intercourse and trade either by sea or land, the epidemic travelling faster by ship or railway than by caravans proceeding on foot. In these climates it maintains itself only for a limited period and then gradually dies out, until again imported from the East.

In the first-mentioned area it no doubt exists permanently as an extracorporeal contagium, varying in activity with the temperature, humidity, &c.

In the second group of areas it does so in like manner, with this difference—that the conditions for developing its activity are of periodical or less frequent occurrence.

In the third group, or temperate climates, it cannot maintain a permanent extracorporeal existence, though as in Spain in 1893 it may be dormant for a year or two. Infected persons infect the soil and water, which in their turn infect other persons; and the epidemic maintains itself for a time determined by meteorological conditions, and with an intensity dependent on the pollution of the soil, water, &c., and general insanitary surroundings.

Thus, though imported on several occasions, it has failed to effect a lodgment in this country since 1866. In Rome, while the sanitary conditions of the population were till recently as bad as they could be, it has since the restoration of the ancient water supply been absolutely insignificant, though raging throughout the rest of Italy: and in Sicily, in 1884, it was excluded by a relentless quarantine, but in the following year it decimated the population.

Dysentery.—I have no doubt that several pathological processes having no ætiological connection are confused under this

name, and that for the most part the cases of so-called sporadic dysentery occurring in this country are but severe forms of intestinal catarrh or enteritis, attended with muco-sanguineous discharges and sloughing of the intestinal mucous membrane—*symptoms* resembling those of true dysentery, but due to totally different causes peculiar to the individual. Chronic dysentery I consider rather an expression for the intestinal lesions and their effects on nutrition, consequent on an attack of the disease, analogous to the destruction of the absorbent structures of the intestine and consequent impairment of the digestive functions which occasionally follow enteric fever. The vehicle of the propagation of dysentery, as of cholera, is the water—other alleged "causes" being simply predisposing; that is, such as render the alimentary canal more vulnerable. The best authorities now believe that dysentery is not in the strictest sense a specific disease, one *sui generis* like cholera or enteric fever, but the result of toxins produced by the common and ubiquitous *Bacillus Coli*, which under special conditions and in symbiosis, that is living in association with certain other bacilli, has acquired pathogenic properties. Its constant appearance in camps and besieged towns is thus explained.

Enteric Fever, except in its universal distribution, resembles cholera ætiologically. Like it, mere proximity to or contact with the patient is almost devoid of danger, the virus being contained in the evacuations, and in water or fomites polluted thereby. By water, I mean, as in the parallel case of cholera, not only the water supply, and milk with which it has been mixed, but the ground water, by the rise and fall of which the soil and ground air become infected, and the poison rises into the air of houses. The vast majority of cases may thus be traced to pre-existing ones, but I will not deny the possibility of sporadic cases arising from originally extracorporeal sources, though the usual origin of cases, in which no history of infection can be traced, is to be found in the unexhausted specific contamination of the soil in previous years.

Diphtheria.—The microbes swarm in the secretions and exudation of the affected parts, and are exhaled with the breath. Infection follows inoculation, absorption, or

swallowing of these, and inhalation of the breath. Fomites are a frequent vehicle of contagion, the vitality of the microbes or their spores being great, and themselves easily diffusible. Extracorporeally, the poison is diffused in the effluvia or exhalations from accumulations of organic matter, and the ground air of infected sites. Water, too, may occasionally serve as a vehicle, though less frequently than air.

Ophthalmia.—Fomites, commonly towels, or inoculation, will infect the healthiest; the microbes are also diffusible in the air of rooms, but in this case appear to require for infection a low state of health in the recipient.

Erysipelas.—Inoculation and fomites are the modes of infection in the so-called traumatic cases, but I hold that the cocci are widely diffused in the air of inhabited localities, and thus infect persons whose resisting power is low, and who happen to present for their entrance a breach of the cutaneous or mucous surfaces.

Septicæmia.—As erysipelas, but the microbes appear to require dead or putrescent organic matter for their habitat.

Tetanus.—Extracorporeal, in dirt of any kind, but always requiring inoculation, and never communicated from the patient to others by ordinary contagion.

Anthrax.—Communicated to man, hitherto, only by inoculation of the discharges either in the recent state or as attached to formites, viz., hides and hair, or wool.

Glanders.—By inoculation of the nasal discharges of horses.

Rabies—hydrophobia—only by inoculation with the saliva of rabid animals, mostly from bites.

Summary of Chapter XV.

Preventible Diseases.

No disease is inevitable, but by preventible diseases are meant those the control or prevention of which is in the power of the State or society rather than of the individual. They include the infectious and infective diseases caused by entrance of bacteria derived from other cases or from the soil, &c. **Malarial diseases** formerly supposed to be derived from the soil and water but now proved to be the result of the entrance of *hæmatozoa* into the blood corpuscles through the bites of certain species of gnats in which they pass the asexual phase of their life cycle. Diseases similarly produced, but by higher animal parasites, are Filariasis, Trichinosis, intestinal, and other worms, and the higher fungous diseases, internal as actinomycosis or external as ringworm, &c.

The most specialised of the **communicable diseases** are those acute fevers the bacteria of which may retain a dormant vitality, but cannot grow and multiply out of the living body, each case being traceable to a previous one; they run a definite course and do not recur. Others of these are of indefinite duration, and may recur. Another large group, most of which may recur, are communicable from man to man, but their microbes have also an independent existence in the soil, so that they may arise *de novo* as well as by personal infection. Some have a definite and others an indefinite duration; and one, tetanus, is not communicable but always derived from the soil. Two only, yellow and enteric fever, confer immunity to subsequent infection. Some appear to be caused by various microbes, and a few by microbes that acquire pathogenic characters only under special conditions.

Some of each of these classes are common to man and other animals, others proper to animals are communicable from them to man, but not from man to man. Scarlatina is rightly considered a **disease of childhood**, the susceptibility thereto and the fatality rapidly diminishing after puberty. Measles, whooping cough (and small-pox in unvaccinated communities), are so simply because of their extreme infectiousness and universality, all ages being equally susceptible, though most adults are protected by an attack in childhood. Enteric fever is most frequent amongst young adults, but the fatality increases with age, as does that of typhus. Diphtheria and scarlatina are most frequent and fatal in childhood.

Communication is effected by (1) inoculation, (2) absorption by mucous surfaces, (3) inhalation, (4) ingestion. Some diseases by one means only, others by more. Aërial conveyance is possible to greater distances in some, as smallpox, than in others, but has been over-estimated. Polluted water is the chief vehicle of cholera and enteric fever, and dysentery. Tuberculosis is mostly inhaled with dust by adults, but the ingestion of milk of tuberculous cows is the usual vehicle in the case of infants. Tetanus, erysipelas, anthrax, glanders, and rabies are propagated by inoculation only. Infection is followed by a period of latency or incubation, fairly constant in each disease. The invasion is in some followed after a definite period of a few days by the eruption. Infectivity persists for a variable period after convalescence.

QUESTIONS ON CHAPTERS XV. AND XVI.

1. What circumstances favour the spread of enteric fever? Discuss the question of the *de novo* origin of its poison. 1894, H. 1889, H.

2. Under what conditions do marsh diseases appear? What are their chief characters? How may they be prevented? 1884, A.

3. How would you disinfect a room and the things in it after a case of scarlet fever? 1885, A.

4. What are the chief substances used for disinfecting air? How do they act? 1886, A.

5. Is it practicable, and, if practicable, is it desirable, to attempt the disinfection of the air contained in a room? Is it conceivable in a sick room? What is really meant or aimed at by "aerial disinfection" after the removal of the patient? and what conditions are indispensable to success?

6. Discuss the several ways in which disinfectants act as germicides. Describe the action and necessary concentration of sublimate, formalin, carbolic acid, sulphurous acid, chlorine, zinc chloride, and permanganate of potassium. To which would you give the preference, and why? To what extent do gases as Cl and SO^2 penetrate fabrics?

7. Compare dry heat, moist steam, dry steam, and boiling

water as means of disinfection, as regards their energy and their practical applicability. To which would you give the preference under different circumstances?

8. In disinfecting a papered, carpeted, and fully furnished room, with heavy curtains, feather bed, and quilts, and stuffed couch and chairs, how would you proceed? What methods would you apply to carpets, sheets, feather beds, stuffed chairs, and the walls and floors respectively?

9. What construction of floors, and what wall surfaces are the least likely to retain infection, and therefore specially advisable in nurseries and bed-rooms?

10. What diseases have been shown to be spread by the agency of milk? In what ways does the milk become contaminated? What precautions should be taken to prevent such contamination? 1886, H.

11. What precautions is it necessary to take to prevent the spread of typhoid (enteric) fever [in the family and in the community]? 1887, A.

12 What is the rationale of vaccination? Give the most important statistics of the results produced by vaccination and re-vaccination. 1887, H.

13. What conditions favour the development of consumption, and what precautions should be taken for its prevention? 1888, A. 1889, A, &c.

14. How do you account for (1) the great decline in the mortality from phthisis and tuberculosis generally in all the more civilised nations? and (2) the marked increase in that from mesenteric and meningeal tuberculosis of infants that has, in this country at any rate, proceeded concurrently with the decline in all other forms during the last twenty years?

15. In what way is the aerial convection of the tubercle bacillus effected and how should it be provided against? Which are the most likely vehicles among foods, &c.?

16. Compare and contrast the methods for preventing the spread of *typhus* and *typhoid* fevers. 1890, A.

17. What are the distinctions between disinfectants, antiseptics, and deodorants? Give examples of each. How should infected bedding be purified? 1889, A.

18. State what you know as to the origin, spread, and mortality of diphtheria in this country, and the methods to be adopted to prevent its extension in schools. 1891, H.

19. What is meant by infection, incubation, invasion, and eruption in acute specific diseases? Give approximately the incubation periods of the following diseases, dividing them into

long and short, constant and variable :—Measles, scarlatina, diphtheria, smallpox, enteric fever, mumps, erysipelas.

20. How is diphtheria propagated? To what is attributed the recent increase of this disease in towns, and what remedies would you propose for its prevention? 1894, A.

21. Describe a disinfecting chamber, explain its action, and for what purposes it should be used. What are the best methods of disinfecting woollen articles, silk, cotton and leather? 1894, H.

22. What precautions should be taken by a community to prevent the spread of infective diseases? 1895, A

23. What are the causes of "scrofula" and rickets? In what classes of the community are these diseases most common, and what principles should be observed to prevent their excessive prevalence? 1896, A.

24. What are the causes of tuberculosis? Explain the chief hygienic measures to be adopted for its control and prevention? 1897, H.

25. Define the terms "disinfectant," "antiseptic" and "deodorant." Give examples of each. Has "saturated" steam any advantage over "superheated" steam in a disinfecting chamber? 1898, H. II.

26. Describe some of the methods recently proposed for disinfection by means of formaldehyd gas. State under what conditions gaseous disinfection is likely to be useful, and when disinfection by steam is absolutely necessary? 1899, H. II.

27. Discuss some of the theories held as to the influence of soil conditions on the spread of enteric fever. 1900, H. I.

28. Discuss the theories advocated to explain "natural" and "acquired" immunity. 1900, H. II.

29. What are antitoxins? How is that of diphtheria obtained? What results have been achieved by its use as a curative agent and how far are they dependent on the period of the disease in which its use is commenced? What is the duration of the protection afforded by its use as a preventive measure?

30. What relation does vaccinia bear to small-pox? By what means may its energy be increased and the risk of inflammatory infection be minimised? What advantage does calf lymph present? How may a new and more effective strain be obtained? What remarkable result has followed this proceeding in Hamburg?

31. What are the relative degrees and duration of the pro-

tection afforded by vaccination in one and in four places and of primary and re-vaccination? Why is the latter operation equally as or more necessary than the former? Illustrate this fact by the experience of Germany.

32. What diseases may possibly be transmitted with human lymph? How may erysipelas *from* vaccination and erysipelas *after* vaccination, *i.e.* (*a*) inoculated with the lymph and (*b*) derived from other sources and infecting the wound subsequently, be distinguished?

33. What is erysipelas? Does it ever arise without a wound or breach of surface?

34. Under what conditions only may unsuccessful vaccination be accepted as proof of insusceptibility to small-pox? Is there any evidence of congenital insusceptibility to vaccination?

35. In what relation do inoculation and vaccination stand to the use of antitoxins as preventives?

36. Under what conditions may protection afforded by preventive inoculations be expected to be permanent and under what to be temporary?

37. What is the cause of tetanus and after what kind of wounds does it appear? Explain the origin of the belief that wounds of the hand and foot are specially dangerous, and the partial truth involved.

38. What is tuberculin and how is it employed to detect the existence of tuberculosis? Can you account for the occasional failure of the test in cases of advanced, though very rarely of early disease? Describe Bang's procedure for the elimination of tuberculosis from a herd.

39. Is tuberculosis ever congenital? In what sense can its appearance in later life be deemed a result of heredity?

40. What is actinomycosis? And how is it communicated?

41. What is known of the etiology and spread of cholera? Explain the phenomenon of its apparent causation by eating unsound food or through drunken bouts during an epidemic, but not at other times, and the value of acid drinks as preventatives.

43. Give a short account of the discoveries of Ross and Grassi as to the real nature and cause of malarial fevers, and reconcile the older notions with our present knowledge. What three factors are necessary to give rise to the disease? Explain the freedom enjoyed by Sir W. MacGregor's party in a mangrove swamp on an uninhabited district in New Guinea, swarming with the *anopheles* or mosquito of malaria, and of the native population of Mauritius prior to 1868, though the Indian coolies brought the disease with them. How would you proceed in the

endeavour to banish the disease from a malarious district, and how would you protect yourself meanwhile against attacks? Explain the action of quinine as a preventive and a curative agent.

45. What do you know of glanders and farcy, and of the use of mallein?

46. By what means is anthrax most frequently contracted by man and how can it be prevented? How should the carcases of infected animals be disposed of?

47. By what means is the plague spread and contracted? Explain the part played by rats, and how is it communicated from them to man?

48. Compare and contrast the relations of enteric fever and of cholera to water supplies, and how far they may be considered communicable by direct infection.

CHAPTER XVI

IMMUNITY

The most infectious and characteristic of communicable diseases, as smallpox, measles, scarlatina, occur as a rule but once in a life-time, one attack conferring a greater or less degree of immunity against subsequent infection. It is otherwise with those which, like cholera, influenza, and diphtheria, are less clearly differentiated from non-specific diseases. As regards cholera and influenza, there is no evidence whatever that one attack renders the individual less liable to infection, and in diphtheria the reverse appears to be the case. These facts must be borne in mind in all speculations on protective inoculations or "vaccination."

The nature and cause of the immunity against subsequent infection conferred by one attack of these diseases, which is, as a rule, directly as the severity of the attack, and inversely as the time that has since elapsed, has given rise to much speculation. It was at one time supposed to be analogous to the arrest of

fermentation as soon as a certain percentage of alcohol has accumulated in a saccharine fluid; but the presumption that any such poison would be eliminated from the system in a short time is a fatal objection to this view, although there can be no doubt that all bacteria do secrete or otherwise cause the formation in and from the fluids in which they grow of some chemical poisons or products, the effects of which can be studied apart from those of the bacteria themselves, by the employment for inoculation of sterilised virus—*i.e.*, of culture fluids which have been subjected to a degree of heat, previously ascertained to suffice for killing the bacteria, or by filtration through a Pasteur filter capable of arresting the bacteria. The sterilisation of a fluid is known by its being no longer capable of causing the growth of bacteria when a portion of it is transferred to another tube containing a suitable medium for their culture.

(1) It is however certain that the phenomena of specific diseases are those of toxæmia, or the effects of toxins, poisons produced by the bacteria in the fluids in which they grow [as alcohol is by yeast in a saccharine solution], whether the juices of the living body or suitable artificial culture media. Toxins are of the nature of alkaloids, albumoses or ferments (enzymes) and will apart from the bacteria give rise to all the phenomena of the disease, except its communicability.

(2) That the spontaneous extinction of the morbid process in an acute specific disease is brought about by several factors, chief among which is the formation of an antitoxin or antidote to the toxin, by the protoplasm of the cells of the living animal, stimulated thereto by the presence of the toxin, with or without the bacteria.

(3) There are also substances, of which little is as yet known, formed by the bacteria or contained in their bodies whether living or dead, having toxic, antitoxic or bactericidal properties.

(4) The blood of some animals is capable of providing a pabulum for certain species of bacteria: and the leucocytes, or certain white blood cells of the blood of some animals, have the power of causing the death of certain bacteria by secreting a bactericidal substance which is, however, overpowered by a large invasion of the bacteria. The resultant of these factors constitutes natural immunity or different degrees of refractoriness.

(5) Acquired immunity may be obtained by repeated injections of non-lethal doses of the living bacteria or of their toxines in increasing quantities. Immunity to the living bacteria (active) is more early acquired but is less lasting than, and does not include immunity to the toxins. Immunity to the toxins

(passive) is less easily acquired, is more permanent than, and as a rule includes immunity to the living bacteria.

(6) A temporary immunity is also conferred by the injection of the antitoxin, which has also a therapeutic value not possessed by the others, being curative of the actual disease, as well as protecting susceptible persons against infection for a time. No antitoxin has as yet been satisfactorily isolated, but the serum of a highly immunised animal is used. In two diseases serotherapy has already attained such success as leaves almost nothing to be desired, viz., diphtheria and snake-bite, in others it is still imperfect.

The procedure consists in the injection of the serum of an animal, usually a horse, susceptible yet possessing great natural power of resistance to the disease, this resistance having been intensified to the highest possible degree by periodical injections of the most virulent toxin obtainable in increasing doses, the animal's power of resistance, *i.e.* production of antitoxin, increasing with the quantities of the toxin injected. The strength of the serum is determined by its power of antagonizing lethal doses of the toxin in the culture fluid on guinea pigs.

To obtain the diphtheria antitoxin the filtrate of a virulent culture of the bacilli is used, but for antivenene, minute but increasing doses of the snake venom itself; no matter what the species, the resulting antivenene is equally efficacious against all.

Most prophylactic inoculations consist of sterilised culture fluids, but in the case of the plague, while Haffkin uses the crude fluid, Lustig extracts the albumose free from all extraneous matter, and Yersin employs a serum. The precise nature of Pasteur's antirabic inoculations is not clear, though their value no longer admits of a doubt, which cannot be said of those practised against cholera and enteric fever, while antitetanic and antistreptococcic injections have not fulfilled the expectations entertained of them.

On the other hand Calmette's antivenene has as yet proved unfailing even when the patient appeared moribund, and the results of diphtheria antitoxin are brilliant, provided the treatment be begun within the first three days. Later in the disease it is of less, and after the first week of no value, for though it will entirely neutralise the toxin it cannot repair the destruction of nerve substance to which the paralytic phenomena are due.

Inoculation

Inoculation, or the induction of the identical disease only in a milder form, by means of virus taken from ordinary cases, has been practised in India, China, and the East generally from the earliest times, as a protection against natural small-pox: the Chinese employing insufflation of the dried and finely-pulverised scabs, and other nations inoculating the fluid contents of the pustules by means of needles or lancets. The practice, which might be distinguished by the term variolation, was introduced into Europe by Lady Mary Wortley Montagu in 1723, but was afterwards abandoned in favour of vaccination, and still later prohibited by law.

The precisely analogous operation of ovination (*clavelisation*), or the inoculation of sheep with their own variola, was extensively practised in Germany, France, and Italy, but, like variolation, it has recently been declared illegal in the Empire.

This method is open to the grave objection that though, when the operation is performed with skill and judgment, death very rarely follows, and the individual acquires the highest attainable degree of immunity, the disease thus artificially induced has undergone no change except as regards severity, and is apt to be communicated to others by the ordinary means of infection, resuming in such individuals its normal virulence. Thus, during the fifty years or so that variolation (inoculation) was practised in England, the total mortality from small-pox was greater than when all persons were alike unprotected. The same result was found to follow the practice of ovination in Germany, and led in like manner to its ultimate prohibition; it being also evidently impossible to stamp out a disease by a procedure that presupposes its perpetuation. I must not, however, forbear to refer to the statement of Brigade-Surgeon Dr. R. Pringle, that when, as in some parts of India, the material used for inoculation is taken only from cases of the inoculated disease, the eruption that follows becomes at length almost as mild and local as that of vaccination.

The next class of protective inoculations are the so-called attenuations of M. Pasteur, as practised by him for anthrax, rouget, and some other diseases of domestic animals. They are based on the observation, or alleged observation, that the microbes of these diseases, if cultivated for some time in artificial media, and under certain unfavourable conditions of temperature, &c., lose much of their virulence, and, injected into the body of an animal induce a very mild attack of the particular disease, which, however, suffices to render the individual insusceptible to infection.

The attenuation of a virus by artificial cultivation, even when conducted under conditions inimical to its development, is by no means a constant phenomenon ; very often bacteria, if they grow at all, retain their character and virulence unimpaired. But admitting, even for the sake of argument, that such attenuation is practicable, the whole procedure is uncertain and hazardous in the extreme. There is no doubt that thousands of cattle and sheep have thus been rendered absolutely refractory to infection by the virus of anthrax ; but there being no means of accurately or even approximately standardising the strength of the attenuations, they often fail to give the desired protection, and thus prove delusive, or they actually cause the death of the animals which it was intended to save from the possibilities of accidental infection.

This uncertainty of the results is fatal to the general adoption of protective inoculation by attenuations among animals, and, *a fortiori*, to its ever being employed in the diseases of man. Besides, even if the risks at present incident to this method should be obviated, it is still open to the serious objection already urged against inoculations with the original virus, viz. that it keeps the disease alive, and involves the constant possibility, not to say certainty, that it will be communicated to previously healthy herds and flocks by the ordinary means of infection. As to man, the only circumstances under which inoculation could be justifiable would be those of an outbreak of small pox in a ship far at sea and crowded with coolies or other unvaccinated and therefore susceptible subjects, many of whom must, unless inoculated, certainly die ; and where the isolation of the entire community at the time, with ample facilities presented for subsequent quarantine and disinfection, precludes the risk of the farther extension of the disease

The third class of preventive inoculations, to which alone the name of vaccination may with any fitness or meaning be applied, are those in which the action of the virus is so modified by its having been passed through the organism of some animal generically different that it produces only a trifling ailment, though giving a considerable degree of protection against infection.

Such is vaccination, and it is simply because "cow-pox," so-called, is not a bovine disease, but smallpox, though profoundly modified, that it protects man against his own variola.

The only application of this method, as yet known, is the Jennerian operation. Nothing analogous has hitherto been even suggested for the prevention of sheep-pox, though it is by no means improbable that some animal might be found which should play the same part in relation to the sheep that the cow has played, and the horse may play to man.

The phenomena of protection can be well studied in vaccination, the immunity against smallpox conferred thereby being, both as regards completeness and duration, directly as the extent and thoroughness of the operation. A single successful insertion protects, it may be, only for a few months; three, four, or more do so for many years. In early life, when growth, involving as it does rapid waste and regeneration of tissue, proceeds apace, the best vaccination loses its virtues in less than ten years, but revaccination at puberty suffices for all ordinary risks for the greater part or the whole remainder of a lifetime. As Dr. Cory quaintly but expressively put it:—"Every one who has been vaccinated is at once in a state of regeneration, from which he tends to lapse into his unregenerate state, the rapidity and completeness of his lapse being in inverse ratio to the efficiency of the operation." This is, I believe, the case with every non-recurring contagious disease, and in all there is also a personal element or factor to be taken into account, viz., that some persons lapse more rapidly than others, be-

coming again susceptible after a longer or shorter period, irrespective of the severity of the attack.

Sheep, goats, and camels are subject to diseases closely resembling smallpox, but though inoculable on man, they do not afford protection against that disease. But we know that—

(1) One attack of variola of the kind proper to any animal protects the individual against subsequent infection by the same.

(2) Inoculation of any animal with the virus of its own variola produces a milder form of the same disease, but affords a protection similar to that conferred by an ordinary attack.

(3) A variola inoculated in an animal other than that whose proper variola it is, may give rise to a modified disease attended by no danger to life; and no longer communicable to any other animal except by inoculation.

(4) This modified disease affords a considerable degree of immunity against infection by any means whatever with the variola whence it was derived. This is vaccination.

Infectious Diseases.

Smallpox is perhaps the most infectious of diseases, yet in vaccination we have a means of protection which we have not in any other; but so long as a large unvaccinated or imperfectly vaccinated population exists in our midst we shall have epidemics from time to time. Insanitary surroundings do not develop the disease, though the overcrowding, neglect of vaccination, and of isolation which coexists with them, favours its propagation.

Before the introduction of vaccination nearly every one had smallpox, just as now almost all persons have measles at some time or other; and the heaviest mortality occurred within the first five or ten years of life, the deaths in later periods being very few, since the population had mostly been rendered insusceptible by having had it already. Now the heaviest relative mortality is still among unvaccinated infants, but the absolutely greatest number of deaths occurs between 15 and 30 years of age, as do the cases of the disease, that is to say, when the protective power of infantile vaccination has begun to wear out, and

before the comparative insusceptibility conferred by advancing age has come into play.

In England the number of deaths from smallpox among 1000 from all causes were in the four decades 1760 to 1800, *i.e.*, before the discovery of vaccination, 108, 98, 97, and 88. In the next five, 64, 42, 32, 23, and 16; and since 1850 only 11, epidemic and intervening periods being taken together.

In fact, the evidence is irresistible for all who are not blinded by prejudice, and the statistics of the anti-vaccinators are falsified by such errors that no credit whatever can be reposed in their figures. Dr. C. J. Pearce, for example, in several parts of his book asserts that the death-rate from smallpox for the five years 1875–79 was in England and Wales no less than 344 per million, whereas the correct figure is 82, and that the mortality has not diminished since the passing of the Vaccination Acts, whereas the mean annual mortality for the whole preceding period for which statistics are available was 420, and for the twenty-eight years, 1854 to 1881, only 196 per million. But still more fallacious, because more plausible, is their mode of manipulating accurate statistics so as to deduce false conclusions from true premisses.

Anti-vaccinationists point to the fact that in the ten years preceding the first Vaccination Act of 1867 there were in England and Wales 41,606 deaths from smallpox, and in the eight years following, which included the epidemic of 1871–72, the heaviest of which we have complete records, 53,933. Very well, but if we classify the deaths according to age we shall find that the great majority of these were born before vaccination was made obligatory, and that their deaths should be credited to the want of compulsion in their infancy.

Age.	Deaths from 1858–67.	1868-75.
Under 5 years	22,885	18,300
5 to 10 ,, ...	4,788	7,981
Over 10 ,, ...	13,943	27,625
	41,606	53,933

If we take three consecutive periods of four years each, instead of one of eight years, subsequent to the passing of the Act, the decline in the mortality will be still more clearly seen.

Age.	Deaths from 1868-71.	1872-75.	1876-79.
Under 5 years . .	11,141	7,159	2,140
5 to 10 ,, . .	4,206	3,775	957
Over 10 ,, . .	14,016	13,636	5,445
	29,363	24,570	8,542

Among the most frequent fallacies are those of comparing the total deaths of the vaccinated and unvaccinated, while ignoring the relative numbers of such persons in a population; and that of persistently refusing to distinguish between the deaths, if any, of vaccinated children under one year of age, and of those who have not yet been vaccinated, assuming that because vaccination at some period, three, six, or twelve months in different countries, is obligatory, every infant born into the world is from that moment a sharer in the alleged benefits of the operation. Whereas the vast majority of deaths under one year are of those who have not been vaccinated. These fallacies might be ascribed to thoughtlessness, but we could expose some so gross that they must have been intended to deceive others, since it is impossible to believe that they could have deceived their authors. For instance, Mr. A. Milnes, pretending to show the absence of any relation between the neglect of vaccination and the mortality from smallpox, gives the percentage of the former in ten selected towns for twelve consecutive years, and the death rate from smallpox for three years only, picked out to avoid including the epidemics at Sheffield and Gloucester, representing the latter as enjoying an almost entire exemption, notwithstanding its neglect of vaccination. When Dr. Flinzner compared the mortality in one epidemic among the (1) unvaccinated, (2) the vaccinated, and (3) those who had already had smallpox, the anti-vaccinator, Dr. Böing, completely reversed the obvious conclusion to be drawn from these figures by making two classes only of unvaccinated and vaccinated, and including those who were insusceptible from having already suffered from smallpox among the unvaccinated who escaped! Thus too, Dr. Keller, of the Austrian State Railways, whose statistics are in high repute among English anti-vaccinationists, omits from his tables all children under two years of age (!) and gives under one head a mortality among the vaccinated of 100 per cent. on the strength of a single fatal case. Dr. Wallace quoting Keller, goes to the further extent of omitting to give the numbers on which the percentages are based!

Much harm has been done to the cause of vaccination by the propagation, which its opponents are inclined to view with complacency, of absurdly exaggerated notions as to its efficacy, *e.g.*, that the protection afforded is, or ought to be, absolute, and bears no relation to the number or size of the vesicles, and that want of success in vaccination or revaccination is evidence of insusceptibility to smallpox infection. It is of the highest importance that the public should be provided with correct information as to what is and what is not vaccination; what it does and what it does not claim to do. There is probably no such thing as an infant insusceptible of successful vaccination; for among 110,728 brought to the stations of the L.G.B. down to the last official returns, not one had been found, but we know well that there are degrees of operative skill. The insusceptibility to the infection of smallpox imparted by successful vaccination is at first almost complete, irrespectively of the degree of success attained, but it is otherwise with the duration of this immunity, which is directly proportional to the efficiency of the vaccination, as is also the modifying influence exerted by the vaccination on any subsequent attack of smallpox. In the case of a child in whom only one insertion has taken, the protection is probably lost after the lapse of a year, whereas, in one with four or five good vesicles, it lasts for ten or more years. But whatever permanent influence a thorough primary vaccination may exert over the remainder of life, revaccination, best performed when the effect of the primary operation has begun to fade, *i.e.*, soon after the tenth or twelfth year, if that were satisfactory, or earlier if it were not, is necessary for future protection. The immunity conferred by re-vaccination is equal to that given by an attack of smallpox itself: thus, of the 14,000 patients admitted into the Homerton Hospital in 1871, only four had been revaccinated, and the only cases among the attendants in the hospitals of the Metropolitan Asylums Board were those of persons who had not been. It is unreasonable to expect perfect and permanent immunity when we know that smallpox itself does not infallibly protect from a second attack. Dr. Neuretter found among 1,133 children under fourteen years of age treated for smallpox in the Children's Hospital at Prague between 1870 and 1873, no fewer than thirteen, or more than one per cent., had suffered previously, nine of them within seven months. Yet no one doubts that smallpox is one of those diseases which occur, as a rule, but once.

But vaccination to be of use must be efficient; not less than four good scars are requisite for safety, and the operation should be repeated at least once, say in the twelfth or thirteenth year, when

the virtue of the primary vaccination has begun to wane, and experience shows that susceptibility returns. Failures must not be considered as evidence of insusceptibility, but the operation must be repeated with more care. The amount of sham vaccination in the world discredits the whole, and is a source of danger to the community.

The importance of revaccination at puberty is such that the two operations should be looked on as inseparable, and the first incomplete without the second. Prior to 1874 even primary vaccination was not required in Prussia and most of Germany. The exemption enjoyed by Frankfort and Nassau from the epidemic which in 1871-3 ravaged Germany as it did other countries caused the Imperial Parliament to adopt and extend to the entire empire the law requiring *revaccination* at twelve years of age, which had been long in force in those and one or two other small states, and to which they owed their immunity. The result has been the almost complete extinction of small-pox in Germany since that year. In the six largest cities of Germany, the mortality from smallpox per 100,000 of the population was reduced from 92 in the ten years preceding to 1·4 in the ten following the passing of the new Act, and latterly not more than ·16, and in some years 0, while in the same number of non-German capitals the decline was only from 136 to 101, and epidemics unknown in Germany have in other countries recurred every two or three years.

Anti-vaccinators have recently endeavoured to explain away these results by attributing them to improved sanitation, whereas they are no less marked in those towns where the old cesspools and other abominable arrangements remain just as there were previously, than in those which have taken the lead in sanitary reform. In this respect smallpox contrasts strongly with the true filth diseases, as diphtheria, enteric fever, and diarrhœa, which, while fast declining before sanitary progress, are as rife as ever where little or no improvement has been effected in this direction. The only connection between insanitary surroundings, poverty, filth, &c., and smallpox is the impossibility of securing the isolation of individual cases and the inevitable propagation of the disease in an overcrowded and badly vaccinated population.

The epidemic of 1884 at Sheffield is not less instructive, that is as regards the protection afforded by a single vaccination only. Of the 100,000 children in that town under ten years of age, 95 per cent. were vaccinated. Among these 95,000 there were 189 cases, and two deaths, and among the 5000 unvaccinated, 170 cases and 70 deaths. The mortality, therefore, among the former was 1 per cent. of the cases and 0·0021 of the whole number, and

among the latter 41 and 1·4 respectively. The actual number of cases among the vaccinated majority was indeed somewhat greater than in the unvaccinated, who were twenty times less numerous, but the deaths among the latter were thirty-five times as great as among the vaccinated. The mortality of the vaccinated was thirty-one times less than of the unvaccinated on the numbers attacked, and 670 times less on the respective classes living.

Among the adults admitted into the hospital there were thirty-two deaths, twenty-one being unvaccinated, eleven vaccinated once, but on an average thirty years previously, and not one of an individual who had been so twice. These figures are unanswerable.

The most complete statistics as to smallpox and vaccination are to be had from Germany, where the military system involves the examination of every man on his attaining his twentieth year. Thus, Staff-Surgeon Evers in 1882 found among 2291 men, the entire surviving male population born in the battalion district of Chemnitz, in the year 1862, 1946 who showed marks of vaccination, and 345 who did not; of the former 26, and of the latter 73 had had smallpox, 1·3% of the one, and 21·1% of the other; no account being taken of those who had died of the disease during the severe epidemic of 1871-72 which had intervened. Of that epidemic Dr. Flinzner, of Chemnitz, has left us records, unexampled for their completeness. The population was a little over 64,000: the cases of smallpox were 3596, and the deaths 249. Analysing these, he shows that 2643 cases and 242 deaths occurred among 5712 unvaccinated, and 953 cases with seven deaths among 53,891 vaccinated persons; 4652 who had already had smallpox escaping altogether. No death occurred among the vaccinated under fourteen years, while 220 (or 80 per cent. of the total mortality) were of unvaccinated children. The period 1870-73 was one during which smallpox raged throughout Europe with a severity unknown since 1838, and it is interesting to compare the mortality in Bavaria, where vaccination was compulsory at some time *during the first two years* of life, with that of Holland, where it was optional. For every 100,000 living at each of the ages 0 to 1, 1 to 5, 5 to 10, and 10 to 20 years, the deaths in Bavaria were 232 (most if not all of them unvaccinated), 10, 3, and 2. In Holland 767, 455, 145, and 75, and at the present time the death-rates from smallpox in Holland and Germany are as 620 to 1. No statistics which do not take account of ages and distinguish between vaccinated and unvaccinated infants, are of the smallest value, for, as we have seen from Dr. Flinzner's figures at Chemnitz, nine-tenths of the deaths occurred among the latter: vaccination may be strictly

enforced, and yet the disease being once introduced, a heavy mortality may occur among the children on whom the operation has not yet been performed, the vaccinated population enjoying immunity.

But the analyses made by the Imperial Board of Health of all *cases* of smallpox occurring within the German Empire furnish evidence, still more irresistible, of the almost absolute immunity conferred by the practice of compulsory revaccination, showing as they do that *for many years there has not been a single case of purely native origin.* Four-fifths of the cases occur on the frontiers, and the primary case in each little local outbreak has been imported directly from abroad, in the person of a foreigner already infected previous to his arrival, or of a German, who, born before 1860, had not come under the operation of the law of 1874, contracting the disease when travelling in one of the neighbouring countries of Austria, Italy, Russia, or France, and returning during the period of incubation. These have occasionally communicated it to infants not yet vaccinated, or to adults who, like themselves, had not been so since their infancy.

Having before me the German Imperial Act of 1874, and annotated abstracts of all previous legislation in the several States, as well as of the debates on the Bill, I have no hesitation in asserting most emphatically, that the reiterated allegations of Dr. Hadwen and the antivaccinators generally, that vaccination was practised as thoroughly before or subsequently to the passing of that act are absolutely false : that the act was based on the Frankfurt not, as they insist, on the Prussian law : and that the statistics of smallpox in the German army and among the French prisoners are contained in the official medical history of the war, in seven huge quarto volumes (to be seen in the Library of the Royal College of Surgeons), the existence of which they persistently deny on the strength of a statement by the late Earl Granville, made a year or two before the publication of this colossal compilation ; and their assertion that the French army was as well vaccinated as the German is equally untrue.

The truth is that though primary vaccination was fairly general in Bavaria, and legalised in Baden, Hanover and elsewhere, it was nowhere enforced except in a few minor states, and there was no provision whatever for revaccination, save in Frankfurt, Nassau and Anhalt. In Prussia and Saxony, in fact in far the greater part of Germany, compulsion of any kind was unheard of, except in the army, with what results is well known, and in houses in which cases of smallpox appeared. The eminent statistician, Körösi of Buda Pesth, ranked Bavaria with Sweden and Great Britain as one of the best, and Prussia among the

worst vaccinated countries in Europe, an opinion fully confirmed by the experience of 1870–2.

The character of the vaccination in the French army may be judged by the fact, that in 1882 the authorities remarked on the great improvement that had been effected since the war, "no fewer than 30 to 35 per cent. of the operations being successful" —the proportion in the German army is 90 to 95 per cent. What, one may ask, was it in 1870 if in 1882 only one man in three was really vaccinated? The German army, unlike the civil population, was well vaccinated, and in an average strength of 788,213 on active service there were 4,835 cases of smallpox with 278 deaths, equal to 6·1 and 0·34 per 1,000 respectively. Among 374,995 French prisoners, the cases amounted to 14,178 and the deaths 1,963, or 380·2 and 52·64 per 1,000, though the German authorities were constantly stamping out the outbreaks that followed each new arrival of prisoners.

The estimate of 23,469 deaths from smallpox in the French army rests on no less an authority than that of the Director-General of the Medical Service, Dr. Chêsne; but its accuracy is denied by some. It is, however, rendered very probable by the reports of Vacher and Le Sueur on the mortality of the garrison in Paris, where, out of a total of 77,231 deaths from all causes, 7,779 were from smallpox.

The strongest, indeed the only plausible, objection that can be urged against vaccination is the possibility of the communication of syphilis, the production of erysipelas or blood-poisoning, and it is alleged of other skin diseases. As to the latter we may state positively that their appearance after vaccination is a mere coincidence, or at most that it may have been accelerated by the febrile irritation set up. Erysipelas will follow the inoculation of septic matter after vaccination; but, its incubation period being under forty-eight hours, it will appear within two days; and the fact of its breaking out, as it almost invariably does, in the second or even the third week, proves conclusively its source in uncleanly surroundings.

Lastly, with regard to syphilis, no one can deny that it has been communicated by vaccination: but such an accident cannot occur without gross negligence, yet a medical man should refuse to vaccinate save from the calf, a child who has the slightest evidence of congenital syphilis, lest he be made a scapegoat for the sins of its father. Such cases have not unfrequently occurred, and no Local Government Board inquiry will remove the obloquy incurred by previous misrepresentation. The employment of calf lymph, though it has no advantage over human as regards efficacy, has the merit of precluding such an allegation.

Animal Lymph and Human Lymph.—The brilliant experiments of Dr. L. Voigt, of Hamburg, who in 1881 succeeded in developing splendid vaccine lymph from the pus of smallpox of the most virulent type by successive transmissions through a series of calves, established the soundness of the opinion first advanced by Jenner, and experimentally verified by Ceeley, Badcock, Thiele, &c., that cowpox is not a disease proper to the cow, but is nothing more than smallpox so modified by its passage through the body of that animal that it has ceased to be infectious and become enthetic only. At present the majority of cases of so-called spontaneous cowpox are doubtless only accidental retrovaccination of the cow. Smallpox is inoculated in the cow with great difficulty, but each succeeding inoculation becomes easier, the virus at the same time becoming progressively feebler, whereas in the human being it may be transmitted through thousands of individuals without serious deterioration. If a new stock be desired these experiments should be repeated, the lymph not being used for vaccination earlier than the eighth or ninth generation or cultivation. This was done shortly afterwards by Fischer of Carlsruhe and by Haccius of Geneva, and again more recently by army surgeons in three different parts of India. Surgeon-Major King having successfully inoculated calves with smallpox virus, and observed a few pustules or vesicles at some distance from the seat of the operation, passed the lymph from these through seven calves in succession, when it presented the characters of a first-class vaccine, in every way superior to that previously in use, and with which were successfully vaccinated no fewer than 4,000 soldiers and 400,000 of the general population, when the Madras Government put a stop to his proceedings and punished him for his departure from the beaten track of tradition and routine!

The results of the revaccinations in Hamburg, where Voigt's lymph has been almost exclusively employed, afford striking evidence of its greater potency and protective power. For the

percentage of successes which until 1895 had averaged 98, began in that year, when the children on whom it had been used first came up for revaccination, to fall rapidly, until it is now under 60, showing that the influence of their primary vaccination remains unimpaired after twelve or fourteen years ; the successful operations being probably mostly of children born elsewhere.

The opacity which appears after a time in all tubes of stored lymph has been show by Dr. Monckton Copeman to be caused by the development of extraneous bacteria, present in the lymph, though originally in negligible numbers. They crowd out the specific microbes rendering the lymph inert. But the addition of some dilute glycerine completely inhibits their growth, and actually causes the potency of the lymph to increase progressively.

Well-selected human lymph answers all reasonable requirements, but if popular prejudice can be overcome by the employment of lymph from calves vaccinated from infants, there is no objection to the practice. But the vesicles in the calf are very rarely as perfect as in the infant, and there is greater risk of unhealthy matter being conveyed thereby.

Scarlatina is a well-defined and very infectious disease, most frequently occurring in early life, and most fatal between the second and seventh years. The incubation period rarely if ever reaches a week, being most commonly between two and five days. The invasion sets in with sore throat, the rash appearing about two days later. The most characteristic remote consequence is an affection of the kidneys, manifested by albumin in the urine and dropsy. It is to a great extent, if not entirely, independent of sanitary surroundings, and communicated solely by human intercourse. It is infectious from the first appearance of throat symptoms to the completion of desquamation or peeling and still later by the breath. Prevention consists solely in isolation and disinfection. After puberty the mortality is very low.

It should be remembered that the disease may be of

so mild a type as not to be recognised at the time, though its nature may be afterwards revealed by the occurrence of dropsy or the communication of the disease to others in severer forms. Like smallpox it occurs as a rule but once in a lifetime, one attack conferring immunity against subsequent infection.

Diphtheria resembles scarlatina in being attended by sore throat and enlargement of the glands in the neck, but early in its course there is albuminuria, leading, may be, to convulsions, though not to dropsy. Its characteristic sequelæ or after-consequences are various forms of paralysis, especially of the muscles of deglutition, loss of sight or hearing, or failure of the heart. Unlike scarlatina it is certainly produced *de novo* by effluvia from sewers, cesspits, &c., and by polluted water, though afterwards propagated by intercourse in the same way, kissing being perhaps the most frequent mode of communication of both diseases among women and children. But diphtheria is by no means so well defined and characteristic a disease, and there is every reason to believe that a large proportion of cases of foul smelling sore throats, especially those traceable directly to septic poisoning and those derived from such by infection, as well as many deaths registered as from putrid sore throat, quinsey, mumps, and even scarlatina, are really diphtheria, as are also nearly all fatal diseases of so-called croup. The typical diphtheria is characterised by the formation of a dirty whitish coating over the mucous membrane of the throat, nose, or windpipe. It may thus be pharyngeal, nasal, or laryngeal at the commencement, and it may extend from any of these regions to the others, though laryngeal diphtheria, if it be severe, is generally fatal before it has time to extend further, suffocation being superadded to the other dangers to life. Laryngeal diphtheria is commonly called croup, but the term is ambiguous, and ought to be banished from scientific language. Some croups are mere catarrhs of the larynx, others spasm of

the glottis; but the rest, including most fatal ones, are diphtheria. Diphtheria may occur any number of times, and the poison adheres with the greatest persistence to rooms, furniture, and clothes.

Prevention.—Good sanitary surroundings, pure air and water, isolation, and disinfection.

Measles is a well-defined disease, intensely infectious, and conferring immunity against future infection. It is independent of sanitary conditions, propagated solely by infection; but the poison if freely exposed to the air does not retain its vitality long, thus differing from all the foregoing. The incubation period is, like that of small-pox, about ten days; then the invasion, marked by catarrh of eyes, nose, and bronchi, lasts about four; after which the rash appears. There is seldom much peeling of the skin. It is very rarely fatal among the better classes, nearly all the deaths registered as from measles being really due to bronchitis and inflammation of the lungs, the results of neglect and exposure to cold.

No age is exempt; the only reason why it is looked on as a disease of childhood is, that being in the highest degree infectious from the first commencement of the catarrh and when its nature is as yet unsuspected, few children, especially in schools, can hope to escape it; but if by circumstances they do, they are just as susceptible to it in after-life.

Prevention.—Isolation alone would be of use, but it is generally begun too late. Disinfection beyond washing, &c., is needless, the poison being of very transient vitality.

Rubella, popularly called German measles from the similarity of the eruption, is essentially different, the two not being protective against one another. There is little or no catarrh, but more sore throat.

Whooping Cough is a highly infectious disease, occurring but once in a lifetime, but at any age, though from circumstances most frequently in childhood. The poison

is not persistent, but is conveyed some distance by the air. Following an incubation of a week or so there is an ordinary cough for about the same period, after which the characteristic symptoms appear, a paroxysm of coughs followed by a deep inspiration, accompanied mostly by a shrill sound, when the same phenomena are repeated. The duration of the marked whooping cough averages six weeks, being sometimes as short as three, but it may be prolonged for months if the child be exposed to cold air. The vulgar belief that children, suffering from whooping cough, should be as much as possible in the open air is most pernicious, leading not merely to an indefinite prolongation of the cough, but to the supervention of bronchitis and pneumonia, to which, as in the case of measles, most of the deaths are due.

As with measles isolation should be carried out so soon as the disease is recognised, but for like reasons special disinfection is not called for.

N.B.—In all these diseases the mucus from the nasal passages and throat is the chief vehicle of contagion, and in diphtheria and scarlatina the use of pocket-handkerchiefs should be forbidden, pieces of soft rag being substituted and burnt as soon as used.

Typhus is a highly infectious and very fatal disease, happily little known in this country. It is closely connected with insanitary conditions, but unlike enteric fever and diphtheria, overcrowding and poor living are important factors in its production. Thus it is confined to the slums of large cities, starving populations, and insanitary camps. It is far more frequent in Ireland than in England, and in Poland than in Germany. It is the scourge of large armies suffering from defeat, ill-fed, and dispirited. In London it has for many years been steadily decreasing, and it never extends to the better houses or well-to-do classes, unless in close intercourse with the infected population. The most ordinary sanitation and the least remove from actual want are sufficient to prevent

the production of typhus, a disease which ought to be, as the plague has long since been, banished from civilised communities.

Its characters are sudden onset, a purple-spotted rash, intense nervous excitement, followed by prostration, and its short duration never exceeding fourteen to twenty-one days ; indeed, if the patient survive the tenth or twelfth day, he generally recovers and regains his health and strength with amazing rapidity.

Typhoid or **Enteric Fever**, though formerly confused with typhus, and still called abdominal typhus in some countries, presents in nearly every point the very reverse of the other. It is slow and insidious in its onset, a full month in duration, and the restoration of health is usually tedious. The rash is insignificant, often absent ; but bowel symptoms, diarrhœa, and ulceration are always present ; hæmorrhage often occurs, sometimes perforation, the former frequently, the latter always fatal ; relapses may follow, and death supervene at any time, even during convalescence. It is like diphtheria, directly dependent on insanitary conditions, and apparently capable of being originated by them. The danger of infection, except by means of the stools and urine, is slight ; and enteric cases are freely admitted into general hospitals, for the poison is propagated by the excreta exclusively. A single evacuation entering a reservoir or river has been known to infect a whole town, though if the water be pure and the dilution great, the fever is usually of a mild type. Broken or defective drains and the entrance of sewer gas into houses, wells polluted by cesspool soakage, and milk diluted with infected water, are among the principal means of its propagation, and the more organic matter the water already contains, the more virulent will be the disease. It is comparatively mild in early life, the fatality increasing with age.

Prevention.—Good drains, disconnection of the house

pipes therefrom, water beyond suspicion, and the instant disinfection and removal from the dwelling of the stools, with the destruction of fouled bedding, are the precautions to be observed.

The Influence of Sanitary Conditions on Enteric Fever.

The death-rate of Danzig before and since the introduction of an improved water supply and of a regular system of sewerage furnishes another striking proof of the enormous influence exerted by such conditions as those of the soil and water on the health of a town population. In 1869 the city was provided with a public supply of pure water, and the present sewerage works were completed about 1872.

From 1863-71 the enteric death-rates per 10,000 had been 11·2, 7·7, 9·8, 12·3, 12·3, 8·9, 7·0, and 11·0, while from 1872 to 1883 they were 8·0, 4·1, 5·1, 3·3, 2·6, 2·7, 1·9, 1·8, 0·8, 1·4, 2·1, and 1·0, giving for the former period an average of 9·9, and for the latter of 2·9, or for the last six years of 1·5. Even this figure does not give a fair idea of the actual mortality, for if we deduct the deaths in hospital of strangers from the neighbouring villages, the rates of the last three years are found to have been 1·1, 1·4, and 0·6.

It is worthy of notice that the enteric death-rate was not appreciably affected by the water supply alone; it was not until the completion, three or four years after the commencement, of the sewerage works that the improvement became manifest, (*Centralblatt für Gesundheitspflege*, 1885, 1er Heft.)

In Munich, too, with a system of sewerage and a water supply second to none in Europe, the enteric death-rate is but one-twentieth of what it was in the days of cess-pits and town wells, but this great fall followed the completion of the sewerage works, preceding the present water supply by several years. Previously improvement of the cess-pits had made a small, and the abolition of slaughter houses a considerable reduction in the mortality, but the partial introduction of purer water supplies had made no difference in the incidence and distribution of the cases.

Chólera.—A disease, the most marked symptoms of which are sudden onset of diarrhœa, with so-called rice water-stools, cramps, depression of surface temperature, cold blue shrivelled skin, changed voice, &c. But none of these symptoms nor all together constitute the disease, since they may be produced by certain poisons or drugs.

By symptoms alone it is impossible to distinguish the early cases in an epidemic from severe summer diarrhœas. A microscopical examination or gelatin cultures from the ejecta will, however, in competent hands, decide the question, for Koch's bacillus is absolutely characteristic of true cholera, and much as it may at first sight resemble Finkler's and others of casual occurrence, it is soon and easily distinguished by the appearance it assumes in its growth.

Without entering on a discussion of the relation between cholera and diarrhœas we may state that true cholera never originates in Europe, but is invariably introduced by human intercourse by sea or land from India and other countries where it is endemic, and that, when introduced, it is propagated by means of the excreta soiling clothes, entering watercourses, or saturating the soil in the same way as typhoid fever, though with the difference that it tends to exhaust itself and die out in temperate climates, and that its severity is directly proportioned to the insanitary conditions of a community. If these be good and the water supply free from possibility of infection, cholera will be unable to establish a firm footing. Pettenkofer maintains that besides the microbe or poison (x) and the susceptible person (z), the co-operation of certain unknown or imperfectly known conditions (y) are also necessary to give rise to an outbreak in any place; as the seed and soil will not yield a harvest without certain conditions of moisture, heat and light. To the neglect of y the failure to account for certain outbreaks must be ascribed, but to ignore or deny the existence of x is an infinitely greater error. If climatic and insanitary conditions could originate the disease, Australia in spite of her rigid quarantine would not have enjoyed absolute exemption. The extreme sensitiveness of Koch's Bacillus to "mineral" acids explains the tendency of neglected diarrhœa, unsound food, drunkenness, &c., to bring on an attack of cholera during an epidemic, though at no other

time, the free HCl in a healthy stomach being usually fatal to the bacilli, but when it is absent through fasting or its place taken by the alkaline mucus of gastric catarrh the power of resistance is lost : hence, too, the value of sulphuric acid mixtures and drinks at such times.

Influenza which, though endemic in Russia, had until 1889 been unknown in central and western Europe, at any rate in the epidemic form, for over forty years, is an infectious specific disease, carried by human intercourse only, though the poison diffuses itself widely in the air as does that of whooping cough, and in a lesser degree of measles. It affects the nervous system especially, in some cases exclusively, but in most the respiratory or the alimentary mucous membranes are also attacked. These latter effects, however, are complications or accidents rather than essentials of the disease. The catarrhal symptoms were more marked in the epidemic of the "forties" than in the last, and led to the name being erroneously applied to any severe acute nasal catarrh, properly called coryza. The gastro-intestinal form is rarer in this country though frequent in Russia. The mortality from pure influenza is not great, but during an epidemic the death-rate from nearly all causes rises 20 to 100 per cent., partly from bronchitis, pneumonia, &c., occurring as complications or sequelæ of influenza, and partly from influenza supervening on other diseases and leading to or accelerating a fatal termination. Consumptives who might have lived for some years then die in a few weeks, and the same result follows when persons suffering from diseases of the heart, kidneys, &c., are attacked with influenza.

Persons who work in crowded factories or offices, or who associate at markets, &c., or live in barracks or schools, are especially liable to be attacked, and like cholera it follows the lines of human intercourse and travels by rail and steamships.

DISINFECTION, ETC.

Incubation.—In attempting to follow any outbreak of infectious disease to its origin, a knowledge of the duration of the incubation period is indispensable. For example if two families were to go to Brighton for a week, and within a day or two of their return to town scarlatina broke out in one and measles in the other, we could feel certain that the fever had been contracted in Brighton, but that the measles infection had occurred several days before the parties had left home. If, on the other hand, the diseases appeared about ten days after their return home, we might as confidently assert that the measles had been caught at the seaside, but the fever since the return. This would be equally true of outbreaks of diphtheria and smallpox respectively.

Perhaps the following may be taken as the nearest approach to accuracy. Constant short incubations:—diphtheria, 1 to 4 days; scarlatina, 2 to 5; influenza, 1 to 2 days. Constant long incubations:—measles, 10 to 12; smallpox, 10 to 15, mostly 12. Variable periods:—cholera, from 1 to 4 days; whooping cough, 7 to 10 or 12 days; typhus, 7 to 14 or 16; enteric or typhoid, 12 to 20; but the vagueness of the invasion makes it difficult to fix the period. The invasion or time that elapses between the commencement of the fever and the appearance of the rash is in scarlatina, 1 to 2 days; smallpox and typhus, 2 to 3; and measles, 3 to 5 days. The corresponding period in whooping cough is about a week.

Isolation.—In instant and complete isolation of persons affected we have the most efficient means of checking the propagation of infectious diseases, but we cannot hope, even by the most rigid system of notification, ever to stamp them out, for not only are they—especially measles, diphtheria, scarlatina, and smallpox—infectious

in the pre-eruptive stage, that is, before they are capable of recognition, but they occasionally run their entire course without their nature being suspected. During epidemics of scarlatina and diphtheria, numbers of persons suffer from sore throats which they believe to be due to cold, and, taking no precautions, they unwittingly communicate the diseases to others. To be of any service isolation must be real. A room should be selected in the topmost story, the door kept closed, a fire large or small according to the state of the weather kept burning, and the windows open as much as possible. Even in winter this can be done without danger by lowering the upper sash and breaking the draught by a blind, a venetian being the best. At the same time the windows on the staircases and in the passages should be wide open day and night, the back door open all day and the front door on the chain. A thorough draught thus maintained throughout the house dilutes and carries off any infection that may escape by accident from the sick room. The other inmates should, so soon as they leave their bedrooms, throw open the doors and windows. Bearing in mind the fact that under ordinary circumstances there is a constant stream of air from the lower to the upper floors, and that the windows of the former act as inlets, the impossibility of isolating a case in any but the topmost rooms will be evident.

The person or persons in attendance on the patient should on no account mix with other members of the family, or if such association be unavoidable, they should take off their dresses in the sick room, and, after washing their hands and faces, put on other dresses kept hanging outside the room or in an adjoining apartment.

All cups, plates, &c., used by the patient and attendants should be devoted exclusively to their use, and washed in the room or outside it, not with others in the kitchen. The room itself, except in the case of measles and whooping cough, the poison of which does not retain its vitality

for any length of time, should be as scantily furnished as possible and devoid of anything calculated to retain infection. All woollen curtains, bedhangings, and carpets should be removed, and only wooden or cane-bottomed chairs retained. The attendant should sleep on an iron bedstead or folding chair bed, not a sofa, and the patient's bed should be of iron. A straw mattress and an ulva or flock-bed of little value which may be destroyed is better even than a hair one, which can be disinfected, but feather beds are inadmissible, as are down quilts and such like unwashable coverings.

In enteric fever, which is always attended with diarrhœa, very often involuntary, it is impossible to avoid the soiling of the bed by the evacuations. During the illness this may be, to some extent, prevented by the use of macintosh, but the bedding should be destroyed, as it is not safe to trust to any disinfection. (The same applies in a still stronger degree to cholera.)

In scarlatina, diphtheria, smallpox, typhus, enteric, and cholera, all soiled clothing and bedding should be immediately plunged in a 1 to 20 dilution of "formalin," or a 1 in 1000 solution of corrosive sublimate (1 drachm to the gallon of water), and left to soak for some hours before being washed. On being taken from this disinfecting solution, they must, even at the risk of spoiling flannels, be thrown into *boiling* water and boiled for some minutes before soaping. But as we said before, pocket-handkerchiefs should not be used at all in diphtheria, scarlatina, and smallpox, pieces of soft linen or cotton being substituted, and burned directly after use.

No infected clothes should, under any pretext, be sent out of the house, unless to one of the steam laundries where special arrangements exist for their separate treatment, or to the disinfecting station of the local sanitary authority.

In typhoid and in scarlatina, the stools and urine should be discharged into a bed-pan or chamber utensil contain-

ing sublimate, Burnett's fluid, or carbolic acid, and stirred with a poker before being poured down the closet, time having been allowed for the action of the germicide ; the closet should be then flushed with the same disinfectant.

After the peeling in scarlatina, or the shedding of the scabs in smallpox, has set in, the patient should take at intervals of three or four days hot baths with soft soap, the hair, previously cut short, being well scrubbed with the same.

In scarlatina and diphtheria the mouth and throat should be frequently sprayed, washed out, or gargled with a pretty strong solution of permanganate of potash (Condy's fluid), or a weak one of chlorinated soda.

Disinfectants.—On no subject does greater ignorance and misconception exist, not merely among the public but among the majority of medical men, than on that of disinfectants. The word is used vaguely and ambiguously to denote deodorants, antiseptics, and germicides. Antiseptics act in the most diverse and opposite manners, some by oxidising and burning, as it were, others by deoxidising and breaking up unstable chemical bodies, some by coagulating albumin and thus delaying putrefaction, and in each case killing the living organisms which are the essential agents in infectious disease and in putrefaction.

Deodorants, as Eau de Cologne, tobacco fumes, camphor, &c., are perfectly useless, merely masking bad smells, though some, as Terebene (sanitas), are oxidisers.

Condy's fluid is a powerful oxidiser, instantly destroying matter in a state of incipient putrefaction. It sweetens the foul discharge from wounds and bad throats, but is nearly powerless to destroy the living germs of disease, and combining as it does with all organic matter with which it comes in contact, is rendered inert in a few moments ; cloths dipped in it are therefore perfectly useless.

Disinfectants which are at the same time germicides

(which Condy's fluid is only to a small extent) are numerous, but some are too expensive, and others, as the much vaunted chloralum, are no better than common salt. Of most practical value are carbolic acid, chloride of zinc, sulphurous acid, chlorine, formic aldehyd, and corrosive sublimate.

Carbolic acid, if sufficiently concentrated, is a fairly powerful germicide. Five per cent. solutions arrest the activity of bacteria, but do not destroy their vitality. Stronger solutions, 10 to 12 per cent. do, but water will not dissolve so much, and the persistent odour is an objection to their use for disinfecting linen. Dissolved in oil carbolic acid is almost inert.

Chloride of zinc is far more powerful. Too concentrated it may injure the texture of fabrics, but not in the weak solutions recommended.

Sulphurous acid (the fumes of burning sulphur), and chlorine gas, are volatile disinfectants. The first is usually produced by burning pieces of sulphur, moistened with spirit in an iron dish—over a pan of water, to guard against fire. Another method is to fill a large lamp, a moderator or duplex, with bisulphide of carbon instead of oil, to wipe it clean, for the liquid is highly inflammable, and stand the lamp in a bath of water : still more convenient, and free from risk of fire is the use of cylinders of compressed or liquefied sulphurous acid, now very general.

Chlorine gas is evolved by mixing binoxide of manganese (1 lb) and common salt (1 lb) in a basin, and pouring oil of vitriol (2 lbs) thereon.

Formaldehyd, a pungent irritating gas, has lately been brought into use as a 40 per cent. solution under the name of "Formalin," and its polymer paraformaldehyd, a white crystalline solid, which, when heated, returns to the normal gaseous form. Inferior to sublimate only as a germicide, it is non-corrosive and does not act on metals. Paraformaldehyd, volatised in a special lamp, the "alformant,"

may be used, as may SO^2 and Cl; but for disinfecting walls, fabrics, utensils or the hands, a solution of "Formalin," 1 part in 20 of water (*i.e.*, of formaldehyd 1 in 800) leaves nothing to be desired.

To disinfect a room, begin by opening cupboards and exposing drawers, &c., saturate the walls and floor with water, seal the chimney and windows with strips of paper and paste; set the disinfecting apparatus to work, then close the door, sealing it in like manner with the windows, and leave the room for twelve or, better, twenty-four hours. On opening it strip the walls of the paper, lime wash the ceilings, and scrub the floors and furniture with carbolic soap.

Corrosive Sublimate.—This is, with the exception perhaps of the corresponding iodide of mercury, by far the most powerful germicide known, a solution of one part in 1000, *i.e.* of a little over a drachm to the gallon of water, being amply sufficient for all practical purposes. It does not injure or stain wood, varnish, paint, plaster, or ordinary fabrics, and if the ceiling be *lime* (not white) washed, and the walls, floors, doors, &c., as well as the furniture of the room washed down with it, no microbe or spore can escape.

Yet it is really far less dangerous to human life than carbolic acid, for the smallest dose of the sublimate known to have proved fatal even to a child, viz., three grains, would require no less than a quarter of a pint of the 1 in 1000 solution. A mouthful would not cause more than temporary discomfort, while the taste would prevent a second being swallowed. Still, as a further safeguard it might be well to add a little laundry blue, and wood spirit to give a smell. The solution of the sublimate is facilitated by adding some common salt, and using hot water.

It attacks metals, but iron bedsteads are protected by the enamelling, and fenders, &c., may be effectually purified by simply polishing.

Aerial disinfection is a misnomer and a delusion. We do not want to purify the old air, but to renew it by free ventilation.

While the room is occupied it is impossible to destroy any germs floating in the air without killing the patient, and after it is vacated, what we aim at is the destruction of the microbes and their spores deposited with the dust on floors, cornices, and other ledges or adhering to the surfaces of walls, &c., which the mere evolution of gaseous fumes fails to do. Indeed, I believe that the success attending the customary fumigations is really due to the scrubbing of floors, stripping off of wall papers and lime washing of ceilings that follow as a matter of routine before the room is again occupied.

Nothing is commoner than to see saucers of Condy's fluid or carbolic acid in a sick room. Now, considering the vitality of bacteria, that they require carbolic acid solutions of over 5 per cent. for several hours, intense heat, or similar heroic measures to kill them, it must be evident that such feeble vapours as can be tolerated in the sick room are utterly useless ; to say nothing of Condy's fluid, which does not give off any vapour at all. Of all living things their spores are the hardest to kill, *ergo* all attempts at aerial disinfection of an occupied room are a delusion and a snare, giving a false sense of security and diverting attention from more efficient measures.

The only means we possess of weakening the infection is to be found in dilution of the poison and its rapid removal, *i.e.*, in the freest possible ventilation.

To disinfect bedding the hair or feathers should be taken out, loosened, and baked for three hours at a temperature above the boiling point of water ; but such a heat, if dry, is almost sure to spoil the articles. There is now no question as to the immense superiority of those apparatus, in which hot air, fully saturated with vapour, but not perceptibly wet, at a temperature of 300° F., is forced under pressure into the interior even of the thickest mattresses, obviating the necessity of taking them to pieces, and without injury to the texture or colour of the most delicate fabrics, as silks or ostrich feathers.

Summary of Chapter XVI.

The spontaneous termination of fevers is due to the production in the organism of an antitoxin, which acts as an antidote to the toxin or poison produced by the bacteria ; and this, in the case of diphtheria, obtained in a concentrated form by repeated inoculations of a refractory animal as the horse, when inoculated into the human being is capable of arresting the disease if already contracted, or of giving immunity for a time, about a month, to those not as yet infected.

Mild attacks induced by inoculating attenuated toxins, and the inoculation of other products obtained from cultures, will often confer a greater or lesser degree of immunity, for a longer or shorter period, according as the disease is, or is not, one that does not naturally occur more than once in a lifetime.

The most perfect artificial immunity is that against smallpox given by vaccination, the artificial disease, originally smallpox, being profoundly modified by having been passed through the cow. But vaccination should be repeated at least once, since the protection afforded by the operation in infancy tends to wear out during the rapid growth prior to puberty. The fresh strains of lymph obtained within the last twenty years by the inoculation of the cow with smallpox have proved far more protective than the older strains in general use.

The practical extinction of smallpox in Germany, which within the last twenty-five years has, from being, except as regards the army, one of the worst, become the best vaccinated country in the world, are absolutely conclusive of the value of vaccination followed and completed by one (or two) revaccinations.

Disinfection, as to which the greatest misapprehension prevails, is the destruction of the bacteria and their spores. Aërial disinfection is a delusion. Persons and excreta, walls, floors, furniture, bedding, clothes, &c., not air, are the objects of disinfection, and there are but few certain and trustworthy procedures. Heat dry or moist, superheated steam or boiling water, solutions of mercuric chloride or of formic aldehyd according to circumstances are best ; carbolic and sulphurous acids, chlorine, &c., are either feeble or uncertain and untrustworthy. Solutions must be of adequate and uniform strength, which must, in the case of excreta, be calculated on the volume of fluid to be disinfected, and must come into direct contact with the bacteria.

CHAPTER XVII

School Hygiene

By School Hygiene is understood the application of general principles to the special circumstances of large numbers of young persons, whether continuously resident in establishments such as orphanages, asylums, and boarding schools, or merely brought together for the purpose of instruction for a few hours daily in day schools of whatever grade.

It embraces questions of the best arrangement of school buildings, their drainage, ventilation, lighting, and warming; seats, desks, and other appliances for teaching; the time to be devoted to study and the effects of excessive or misdirected mental work on the health of children, the value of games, gymnastics, &c., dietaries, punishments, discipline, and the prevention of the spread of infectious and contagious diseases.

On some of these points there is little to be added to what we have already said, but others, as the preservation of eyesight and the prevention of infectious disease, demand special consideration.

School Buildings.—All that has been said on the subjects of building materials, foundations, and the prevention of damp, on the position, interception, and ventilation of drains, the water service, &c., applies equally to schools and private houses, but the water-closets should never be placed in the basement. They should be at some distance from the building but approached by a covered way; and trough closets, as described in the section on latrines, are to be preferred to ordinary closets, their care being committed to a special attendant.

The basement, if for two-thirds of its height above the ground level and opening into a wide area with no direct

communication with the rooms above, may advantageously be utilised in public day schools as a cloak room or cloak rooms for the two sexes, where by means of hot-water pipes and free ventilation the wet clothes of the pupils may be dried, the floor being of concrete and so constructed as to carry off the droppings from cloaks, umbrellas, &c.

Warming.—Schools consisting of but few rooms may be warmed by open or closed stoves, but such should be so constructed as to afford ventilation and to warm the incoming air. If open they should be of the Galton pattern; if closed, the best arrangement is one adopted in Canadian schools, shown on page 226.

Series of school and class rooms are far more efficiently warmed by hot water or steam pipes from a central apparatus in the basement. Rooms of different sizes can be kept at a uniform temperature by varying the number of such pipes, and by concentrating them in coils in one or more parts of the larger rooms.

Ventilation.—This is by far the most difficult problem in school architecture or management. With the grossly insufficient allowance of cubic space sanctioned by the Education Act and Code, viz. 80 cubic feet per head, or that of the London School Board 130, which is little better, it is quite impossible to maintain the lowest permissible standard of purity of the air. That such a limited space per head should be tolerated on the part of the legislature is nothing short of a scandal on our boasted civilisation.

We have shown (see pp. 168 and 169) that to maintain continuously a permissible impurity of ·6 of CO^2 per 1000—*i.e.*, ·2 of respiratory or added CO^2, 3000 cubic feet of fresh air must be supplied hourly per head, and that to renew the air three times in an hour, each individual requies a cubic space of 1000 feet. In schools such an ideal may be impracticable and utopian, but since no injurious effects seem to follow the continuous inhalation

of an atmosphere containing ·8 per 1000 of total CO^2; and since, if the incoming air be agreeably warmed and moistened to the corresponding degree, and the inlets and outlets arranged with the utmost skill, it may be changed six times in an hour without inconvenient draughts; 500 cubic feet per head may be assumed as sufficient.

But though not less should be allowed in schools of a higher class, where the fees can be proportioned to the outlay, or where the primary cost is paid out of endowments, &c., such an expense would never be submitted to by the ratepaying public; and, as a mere matter of necessity, we may, under protest, concede that the Canadian allowance of 250 cubic feet per scholar, will suffice in board and other elementary schools, on the condition that all the arrangements for heating and ventilation in combination are carried out on the strictest scientific principles, and that the most thorough perflation of the entire building is performed before and after each attendance, and in the pause which is, or ought to be, made in the longer morning sitting.

By these means, and by open windows where and whenever they can be borne, it should be the endeavour of the teachers to maintain the air at such a degree of purity that no one entering from the street would perceive any really disagreeable odour, or more than what is commonly called a slight degree of closeness. Then, not only after the morning and afternoon meetings, but also during the interval allowed in the former, the room should be entirely vacated, and every door and window thrown wide open. It would be well if, even by prolonging the morning meeting, the pause could be extended to twenty or thirty minutes, and the teachers were to join the children in the playground. But, under the pressure of the "Code," the pause, instead of being used for the recreation of the children and for airing the school, too often degenerates into a mere suspension of actual teaching, the teachers, if not also the scholars, re-

maining at their desks, and the atmosphere at the end of the three hours becoming foul and depressing in the extreme.

Lighting.—This is the other greatest difficulty with which we have to contend, and the problem is closely bound up with those of desks, and other appliances of teaching. The observations of Professor Cohn, of Breslau, confirmed by those of others in Germany, France, America, and in this country, show everywhere an alarming increase of short sight and other defects of vision, in direct ratio to the progress of "Education" in the sense of schooling, which may be ascribed without hesitation to the combined influences of deficient and ill directed illumination, faulty postures, and small or indistinct type.

The most perfect ease in reading, or in fine work, is felt in the open air on a summer day when the sky is overcast. Under these circumstances the light is ample, but it is perfectly diffused, there is neither glare nor shadow, and the light may be said to come from all sides, but from no one in particular. The nearest approach to this is to be found in the electric light, if so placed as to be concealed from view, as it is in the new Houses of Parliament at Berlin.

From this we may infer that so long as the light does not fall on the eyes, either directly or by reflection, it can scarcely be too strong; and that, when artificial illumination is used, the light should fall on the paper or work, the eyes being in the shade. This is the arrangement adopted in billiard rooms, and secured by so-called reading lamps, the illuminating power being increased by reflection downwards from the inner surface of the lamp shade. These lamps are, however, obviously inapplicable to the requirements of schools.

Even more hurtful to the eyes than a direct light is the heat given off from gas and oil lamps, which causes dryness and irritation of the conjunctiva, unless the lamps

be at a distance so great as to involve a considerable loss of illuminating power. The freedom of the electric light from this objection is not the least of its recommendations. Lastly, the source of light should be steady, for flaring and flickering flames weary the muscles of the interior of the eye, by incessant changes of accommodation.

Short-sightedness, or myopia, is hereditary in some cases, but is most often induced in early youth by reading in an insufficient light, and since "insufficient" is a relative term it follows that the type of reading books, especially in the lower standards or classes, should always be as large as is possible. Otherwise, in order to obtain a larger image on the retina, the book is held closer to the eyes than it should be, with the result of destroying the power of focusing the eye to any greater distance.

Asthenopia, or weak sight, is due to several causes, among which is hypermetropia, a condition always congenital and often hereditary, in which the horizontal axis of the eye is shorter than the normal, so that a constant effort is required to prevent the rays from forming a focus behind the retina. Hypermetropia is remedied by the use of proper convex glasses.

Holding the head down over the book or paper tends to congestion of the vessels of the eye and to impairment of the sight.

The normal focal length of the healthy eye is, for reading all ordinary type, about twelve or fourteen inches; and for writing, fourteen, sixteen, or eighteen inches, according to the size and character of the letters.

Much inability to follow the instruction of the teacher, especially in black board[1] and such like lessons, is in reality owing, not to any want of intelligence, but to de-

[1] Why need we have *black* boards at all? Em. Thieben of Pilsen supplies white slabs with special pencil and ink. The pencil marks are easily rubbed off, and the ink rubbed out with soap and water. The cost is not more than that of slate.

fects of vision and of hearing, which, though so slight as not to be noticed in ordinary and close individual converse, may, under the conditions of collective teaching, be taken for dulness of comprehension.

Teachers should be instructed in the simpler methods of testing the sight and hearing of children, and provided with a few sheets of test types, &c., enough to enable them to detect any marked deviation from the normal standards.

Natural Illumination.—It is almost superfluous to observe that the admission of direct sunshine into a schoolroom is most annoying, if not actually painful. A south aspect is consequently to be deprecated, unless there are windows on the north wall also, when the former may be of ground or tinted glass. Otherwise blinds are necessary, and these are always inconvenient and objectionable, while if the windows themselves be ground or dimmed they give an insufficient light at other times. Provided the window space be ample and the light be not shut out by neighbouring buildings a north aspect is most agreeable. It is generally preferred by men who work much at the microscope, and at the Eye Hospital at Breslau, Professor Cohn has chosen a north aspect for the rooms where the examination of the patients and operations are performed.

Much has been written in condemnation of cross lighting, as if it were in some way specially injurious, but the objections thereto are groundless, since nothing can be better than a clear *shadowless* uniform light, assuming of course that the direct rays of the sun are excluded. Thus roof lighting where practicable is the very best, but failing this, opposite windows facing east and west are to be recommended, since in rooms so arranged there is during school hours no direct sunlight for the greater part of the year. Should circumstances permit, windows may be made in the north wall also, since, barring sunshine, there can never be too much light. But the light must come *direct from the sky*, and no part of a room may be deemed sufficiently lighted from which a certain extent of sky cannot be seen. In the country this is easily attained, but in towns the houses on the opposite

side of the street render such illumination difficult. In the accompanying figure (fig. 33), which represents a building of several stories, forming part of a street, the opposite houses of which are of the same height, it will be seen that each room is divided into two regions of different degrees of illumination, by a plane, *a c*, formed by a line drawn from the ridge of the roofs of the opposite buildings and the upper border of the windows. Below this plane the light is sufficient, or at any rate is "sky-light"; above it is insufficient, being diffused and reflected, not direct. In the upper floors this plan strikes the farther walls: in these the whole of the occupied part of the room is in the

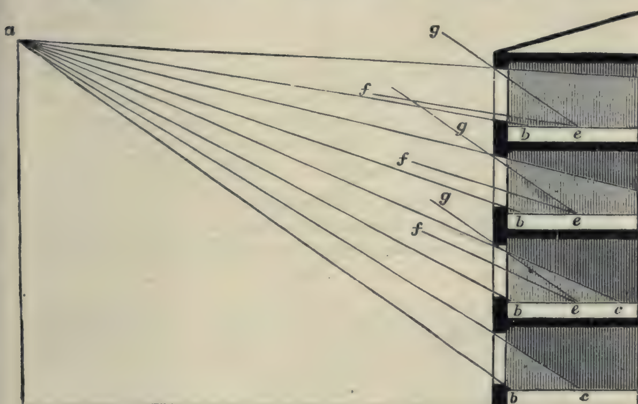


FIG. 33.

light, but in the lower stories it falls on the floor and a greater or less part of the floor space and desks will be in relative darkness, and unfit for reading, writing, or needlework.

But this is not all: the intensity of the light depends on two factors, the angle of incidence, and what, for want of a better term, we may call the angle of aperture, meaning thereby the arc of sky visible at any given point in the room. This is shown in the figure by the lines *fe*, *eg*, and it will be seen that this angle, greatest in the uppermost floor, diminishes as we proceed downwards, until on the ground floor it vanishes altogether. Dr. Förster, of Breslau, lays it down that the angle of aperture

should never be less than 5° of arc in any part of the room. The effect of increased obliquity of the incident rays in reducing the intensity of the illumination is shown in fig. 34, which represents a number of equal pencils of light, *a*, *b*, *c*, *d*, *e*, each containing 10° of arc proceeding from one luminous point *o*, and therefore under like conditions of equal illuminating power; but when falling on a horizontal surface, covering sections increasing as they depart more and more from the perpendicular; the intensity of the light in the several sections will then be inversely as the squares of their widths, representing the tangents of the respective angles, and in the sections *fg*, *ik*, and *kl*, as 1^2, $(\frac{1}{2})^2$ and $(\frac{2}{7})^2 = 1$, $\frac{1}{4}$ and $\frac{1}{12}$. Förster has come to the

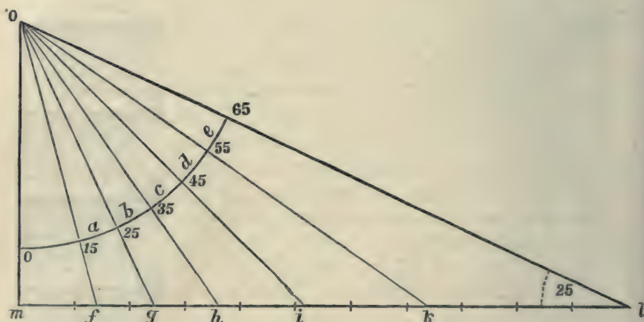


FIG. 34.

empirical conclusion that under no circumstances should the angle formed by the upper border of the pencil with the floor be less than 25°.

In houses forming part of a street the angular aperture is, as we have seen, greater in the upper stories, but in schools, especially for girls, the ascent of many stairs is undesirable. The requisite amplitude of angular aperture is rather to be sought by increasing the height of the rooms, by carrying the window heads nearly to the level of the ceiling, the sills being four or five feet above the floor, and by avoiding the proximity of other buildings on the side from which the light is derived. Thus, if the aspect selected for lighting be that on which the street lies, the school should be

thrown back as far as possible, the playground intervening between it and the street; if, however, the street side be unsuitable for the purpose, the school-house may abut on it, and the light be admitted from the playground behind.

The evils resulting from a too great inclination of the rays of light are to be avoided by increasing the height of the rooms and windows, and still more effectually, by reducing so far as possible the relative width of the rooms, which should on no account be greater than $2\frac{1}{2}$ times the height of the window heads from the floor. This ratio gives an angle of $25°$ to the rays reaching the floor on the farther side; but it would be well if the width of the room did not exceed twice its height. A strong argument in favour of cross lighting from east and west on the right and left hand of the scholars is, that the angles formed by the rays of light with the floor from opposite sides are added, and the intensity of the light obtained is thereby doubled; while, if the windows are placed laterally as regards the scholars, care being taken that the light on the left hand shall be the stronger, and the direct rays of the sun excluded so far as possible, the objections urged against such cross lighting are, we believe, purely imaginary.

In all cases whited ceilings reflect additional light, while tinted walls are grateful to the eyes of the workers. Black boards and maps should never be placed between windows, but, if fixed, on the opposite dead wall.

Artificial Illumination is more difficult in some respects, though independent of the position of the building itself. Heat and glare on the eyes, and shadows on the desks, are alike to be avoided, and this short rule condemns at once a large number of arrangements very commonly met with. The reading lamp, or individual system, is perhaps impracticable in ordinary schools on economic grounds, but we cannot see why, with fixed desks, the billiard table method might not be adopted. It is true that the walls would be in relative darkness, but for black board or wall map lessons, one or two sun-lights might be fixed near the ceiling, where they would illuminate the wall in question without incommoding the eyes of the scholars, and they might be utilised as aids to the ventilation.

Electric lights, the incandescent or glow light, would be preferable to oil or gas, both for the shaded "billiard table" lights and for those on the ceiling, not only on account of the greater purity and intensity of the light, but even more from the absence of heat and of the products of combustion, which add so seriously to the deterioration of the air. The master of Holy Trinity National Schools, Eastbourne, the first, we believe, of elementary schools in which it has been adopted, testified enthusiastically to the absence of drowsiness, and the improvement of the work both of teachers and scholars during the winter afternoon meetings of his school.

School Desks and Seats.—This question is closely bound up with that of lighting in its influence on the eyesight,[1] and has also important bearings on the growth of the less vigorous children, faulty posture in the case of such inducing spinal curvature, round shoulders, and contracted chests. It is true that at some of our great public schools, as Eton, no ill effects can be traced to the retention of forms and desks of the most antiquated and objectionable kind, but weakly boys are rarely admitted, and the compulsory systematic practice of football, cricket, and other athletics, which is not enjoyed by the children of the poor, nor by girls in any class of society, more than compensates for the error. The example of the School Boards has led to a great improvement in the general form of seats and desks, and some of the patterns now sold leave little to be desired. Those constructed for one or at most two scholars are decidedly preferable to longer ones, and were it not for the greater cost, those which are capable of adjustment by screws and rack work would be best of all. But most Boards now recognise the fact that this is a department in which

[1] The ablest and most exhaustive discussion of defective eyesight, and the influence of lighting, desks, writing, &c., thereon, is to be found in Cohn's *Hygiene of the Eye in Schools*, an English translation of which has been published by Simpkin and Marshall.

a much larger outlay must be made than formerly, and it will be sufficient to indicate the principles or features that constitute a good desk, leaving the choice of the actual pattern to those concerned.

The height of the seats should be such that the feet of the children, whatever their size, may rest firmly on the floor, the backs should follow the curve of the spinal column, and the seat may be hollowed or slant a little backwards.

The desks should be provided with a horizontal ledge for ink stands, and a fixed shelf below for books or slates. The desks when in use should project about two inches over the seat. By some means or other—the simpler the better—they should be adjustable at different angles for reading (40°) and writing (10°); and either the seats or the desks should be capable of being so swung or shifted that the pupils may, when desired, stand with ease in their places. They should be of four different sizes for children of from five to fifteen years of age. There should not be more than four rows of double desks, for wider classes are less easily supervised, and ample space should be left between the blocks of desks, and between these and the walls.

Where expense is not an object, and every pupil can be provided with a separate desk, the Glendinning is probably the most perfect, and we would recommend it, especially for girls' high schools. But in elementary schools the question of cost must be taken into account, as well as the liability to injury, incident to more complex mechanisms.

Another desk, the "Hygienic," devised by Mr. Priestley Smith, and sold by the Midland Educational Company, Corporation Street, Birmingham, so completely fulfils these conditions, and is so simple in construction and moderate in price that we cannot but recommend it, and reproduce that gentleman's observations on the requisites of a perfect desk, with those of Mr. Rooper, H.M. Inspector of Schools, on the correct attitudes for reading, writing, etc.

Mr. Priestley Smith says (*Ophthalmic Review*, June, 1886) :—

"Much ingenuity has been devoted to the construction of school desks and seats, and very many different models, each claiming some advantages, have been publicly exhibited during the last few years. At the request of the Midland Educational Company, I have lately designed a School desk which embodies the recognised essentials in as simple and inexpensive a manner as seems to me to be possible. These recognised essentials are as follow :—

"1.—The seat must be of such height as will allow the scholar's feet to rest flat upon the floor or footboard, and broad enough to support the greater part of the thigh.

"2.—The seat must have a back placed at such height as to fit the hollow of the back below the shoulder blades, and support the body in a vertical position.

"3.—The near edge of the desk must be just so high above the seat that when the scholar sits square and upright with elbows to the sides, the hand and forearm may rest upon the desk without pushing up the shoulder.

"4.—As used in writing, the desk must have a slope of 10° to 15° (about 1 in 5) ; as used in reading, it must support the book at an angle of about 45°, and at a distance of at least 12 in. from the eyes—16 in. is better (30—40 cm).

"5.—As used in writing, the edge of the desk must overhang the edge of the seat by an inch or two, in order that the scholar shall not need to stoop forwards, and that the support to the back may be maintained.

"6.—Either the desk or the seat, or some part thereof, must be movable at pleasure, so that although the desk usually overhangs the seat, the scholar may be able at any time to stand upright in his place.

"7.—The desks and seats must be of various sizes, in order that the foregoing conditions may hold good for scholars of various ages.

"Adopting with little alteration the proportions given by Snellen for the various parts of his desk, I have, for the sake of convenience and economy, slightly altered the progression, and reduced the number of sizes to four. Instead of advancing by increments of one-tenth, which is doubtless the right method from the theoretical point of view, I divide the scholars according to their heights into four classes advancing in each case by six inches ; thus 3 ft. 6 in. to 4 ft., 4 ft. to 4 ft. 6 in., 4 ft. 6 in. to 5 ft., and

5 ft. to 5 ft. 6 in. The dimensions of the desks are suited to these four heights. The table on the following page gives the dimensions of my desk—the "Hygienic Desk," Nos. 1, 2, 3, and 4.

"Its general construction is shown in the subjoined figures. The standards and the cross-pieces which unite them are of cast iron. The back, the seat, the top of the desk, and the shelf beneath it, are of wood. The only points which require description are the book-rest, and the arrangement by which the desk is made movable at pleasure.

FIG. 35.

FIG. 36.

"The flap which supports the book does not extend the whole width of the desk, but occupies the middle portion only, leaving room for an ink-pot to be let into the wood at the side of it. The flap when in use is supported by a small stop which hangs from its further edge, and which, though quite firm, can be pressed back by a touch of the finger when the book-rest is no longer wanted. The flap is pivoted in such a way that its near edge sinks below the surface of the desk when the flap is raised, and thus creates a groove for the book to rest in (see fig. 36).

"The wooden top of the desk is screwed to two sloping cast

iron brackets which pass from back to front, one at each side of the desk. Each of these brackets carries beneath its lower or horizontal border a round iron rod, the two ends of which are fixed to the bracket. The rods slide freely through holes or eyes on the upper surface of the standards. By this means the desk is able to slide upon the standards in a direction towards and from the scholar. When the desk is pulled forward a notch in the near end of each rod engages with the eye in which the rod slides, so that the desk is secured in this position, and is not

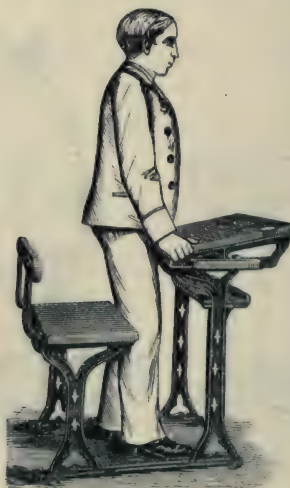


FIG. 37.

liable to slide away from the scholar if he leans against it. By lifting the front edge of the desk the notches are disengaged and the desk is easily pushed back, so that the scholar can stand up in his place. This is a mechanism which does not get out of order, and which cannot injure those who use it, or be injured by them The whole desk can, I believe, be made at a cost not much greater than that of many of the old-fashioned un-hygienic patterns now in use."

"HYGIENIC DESK."

HEIGHT OF SCHOLARS.	No. 1. 3ft. 6in.—4ft. 107-122cm.	No. 2. 4ft.—4ft. 6in. 122-137cm.	No. 3. 4ft. 6in.—5ft. 137-152cm.	No. 4. 5ft.—5ft. 6in. 152-168cm.
a. Height of seat from floor	13ins. 33cm.	14½ 37	16 41	18 46
b. Breadth of seat	10 25·5	11 28	12 30·5	13 33
c. Height from seat to edge of desk Height from seat to top of back	8ins. 20cm.	8¾ 22	9½ 24	10½ 26·5
d. "Overhang" of desk	1 2·5	1 2·5	1½ 4	1½ 4
e. Play of desk	4½ 11·5	4½ 11·5	6 15	6 15
f. Breadth of desk (front to back)	15 38	15 38	17 43	17 43

Slope of desk 1 in 5.

Mr. T. G. Rooper (H.M. Inspector of Schools) says :—

I. THE DESK AND BENCH.

"1.—The height of the desk above the bench should be such that when the child is sitting down, he can place both his fore-arms comfortably on the desk, without raising or depressing his shoulders.

"2.—The height of the desk above the floor or surface on which the foot rests, should correspond with the length of the child's leg from knee to heel. When the child is sitting down, his legs should not dangle in the air, nor should his knees be elevated above the bench.

"3.—The bench should be wide enough to give support not only to the seat, but also to the upper part of the thigh. It should be at least 10 inches (but better 12 inches) wide. To prevent slipping forward, the bench should be hollowed out towards the back to the depth of an inch.

"4.—Every bench should provide a support for the back of the sitter. This may consist of a board fixed at the back of the bench, at right angles to the seat. The board should be hollowed out in such a way that the upper part of it may fit the concavity of the back. The exact height of the back would vary with the size of the child, but it will be from 6 to 7 inches.

"5.—The desk must overhang the bench during the writing lesson, in order that the child may be able to sit upright, and at the same time support his back. This posture is only possible when the desk overhangs the bench from 1½ to 2 inches.

"6.—The desk should not be level for the writing lesson, but slightly sloping. The slope should not exceed an angle of 20 degrees. The difference between the upper and lower edge of the desk, therefore, should be about three inches vertically.

"7.—As the desk, which is most suitable for writing, is inconvenient for other purposes, the easiest plan of adapting it to all uses is to make the upper part of it movable.

"8.—Desks of appropriate sizes should be provided for each class.

2. The Posture in Writing.

"1.—The writer should sit upright, and should lean his back against the support provided for the purpose.

"2.—The shoulders should be kept parallel with the edge of the desk. The writer must not be allowed to screw the body round or to rest the chest against the desk. There should be a space of an inch or a little more between the desk and the body.

"3.—The weight of the body should be disposed evenly on both bones of the seat.

"4.—The head should not droop forward, much less lean on the arm. It may be slightly bowed forward, and may move a little from side to side as the eye follows the writing.

"5.—The forearms, and not the elbows, should rest on the desk. The pen should be passed across the paper by a movement of the hand and not of the arm.

"6.—The point of the pen should be at least ten inches (better twelve) from the eye.

"7.—To make compliance with the above directions possible, the paper or copy-book must lie opposite to the middle of the body.

"8.—The paper must not lie square on the desk before the writer but it must be tilted or askew.

"The lower edge of the paper and the lower edge of the desk should form an angle of from 30—40 degrees.

"The paper is rightly placed when the down strokes are being made at right angles to the edge of the desk.

"The common attitude for writing often ordered by teachers with the words, 'Half turn right, left arm over slates,' is liable to cause injury both to the spine and to the eyesight."

Excessive and Mis-directed Mental Work.—We cannot afford space to do more than allude to a subject which, under the descriptions of over-work, over-pressure, and "uber-bürdung," has been long and hotly discussed in this country, in America, and in Germany. And speaking from long and practical experience as physician, sanitarian, and school manager, I did not hesitate, before the recent radical revisions of the teaching and inspection of public elementary schools, to state my opinion, that, "the requirements of the Codes for elementary schools were wrong in principle and injurious in practice, and devised in almost total ignorance alike of the laws of physiology and of psychology as well as of the art of teaching. Instruction was substituted for education, and under the pressure of 'payment by [so-called] results,' instruction necessarily degenerated into cramming. The moral and reasoning faculties were neglected, while the memory was strained precisely in the field, that of facts and figures, where in childhood it is weakest." Young children have wonderful powers of observation and of acquiring languages, and take the greatest interest in description, poetry, and narrative. The first-named faculty is recognised in Fröbel's kindergarten system, and every one knows how they will pick up and speak fairly two or even three languages in as many years, while still unable to comprehend the statement of a rule of grammar. Indeed it is more than doubtful if the majority of those who pass through our schools ever really understand these rules which they learn by rote ; and abstract generalisations of any kind are distasteful to them. The mathe-

matical faculty is rarely developed until a later age, and prior to this the teaching of arithmetic, as commonly pursued, does, perhaps, more harm than good, while chronology and statistics are little better.

Besides the exclusive attention to book work, the vulgar habit of looking on a black coat as constituting a "gentleman," for which the middle classes are themselves to blame, has undoubtedly tended to beget in the boys of the working classes a distaste for, if not a contempt of, manual and mechanical work, and a desire on the part of all the more intelligent lads to aspire to the position of clerk. It is to be hoped that the technical schools may have the effect of counteracting this result, for while a working man cannot be too well educated, he must be taught to feel the dignity of labour and to cherish an honest pride in his craft, to realise the truth that the sober, thrifty, and well-to-do skilled mechanic may well be more of a gentleman than the struggling clerk ; that carving wood or forging metal is grander work than posting ledgers ; and that whether he stand at the lathe or at the desk, whether he handle the chisel or the quill, "the man's the gowd for a' that."

Well-fed children from the comparatively cultured surroundings of the respectable homes of intelligent artisans, do not suffer appreciably by being subjected to the treatment of a Procrustean Code, but it is quite otherwise with the children of poor and ignorant parents ; while work conducted in the impure atmosphere of the average school tells heavily on them and on the teachers. Most of all do the female pupil teachers suffer from the combined strain of learning, teaching, and maintaining discipline, and from hurried and irregular meals, without the set-off of active recreation and exercise in which the male pupil teachers find relief.

Home lessons should never be imposed on children of either sex under twelve years of age, and up to fourteen or fifteen years not more than two hours should be thus employed. If all that is needed cannot be taught during the four or five hours in school, either too much is demanded or the system of tuition is an erron-

eous one. Evening work is doubly hurtful to the brains of children, and sooner or later affects their health in one way or another. They sleep soundly after boisterous play, but are wakeful and liable to headaches, loss of appetite, and so on, after evening study.

We cannot conclude this section without some reference to the so-called higher education of girls, which, carried on under the pressure of competition and examination just at the time when all that differentiates them physiologically from boys is in rapid evolution, is fraught with danger to their health and capacity for their proper functions as the mothers of the race.

So long as maternity is the peculiar function of one sex, it is idle to talk of equality in the sense of identity of powers, whether physical or mental. It is impossible to dissociate body and mind, and there are sexual differences in each correlated the one to the other. In her bodily organisation, woman, though the weaker, is not merely undeveloped man, but in their mental characteristics the difference is still less one of absolute superiority and inferiority in general. Each is at once superior in some respects and inferior in others. They are, in fact, complementary the one to the other, and their union, in which each supplies what the other lacks, constitutes the ideal of humanity and underlies the Christian idea of marriage.

Sex in mind is implied in the very words "manly" and "womanly," which, however, do not denote contrary or opposite conceptions, as good and bad, or strong and weak, connoting rather the like powers and characters possessed in inverse ratio, but harmoniously balanced in each. It is tacitly admitted whenever we speak disparagingly of a *masculine* woman or an *effeminate* man, expressions which would otherwise be meaningless.

A man's conduct and actions are, or should be, shaped by strength of will, reason, and judgment; a woman's are guided rather by her feelings and emotions, to which she

owes her instinctive, almost intuitive sense of right and wrong, and the faculty commonly known as tact. She is a strong, perhaps unscrupulous partisan, but rarely capable of forming an impartial judgment.

The successes obtained by women in examinations in no way invalidate this statement, for girls are apter learners than boys, but academic distinctions are no guarantee of future greatness. Acquisition, imitation, and execution are one thing ; discovery, invention, and creation are another. The former they possess in a high degree, the latter are the prerogative of man.

Education will not explain this, for *poeta nascitur non fit* is true of all genius, which is *innate*. In music we have a crucial test, for here, at least, women have long had the advantage of instruction, and there can be no "mute inglorious" Handels or Mozarts for want of being taught to play. We have women who paint, and women who write verses, but where is one who even approaches the great masters in painting and sculpture, in poetry and the drama, that have arisen in every age and land? Women have plied the needle from the dawn of civilisation, but it was a blacksmith who invented the sewing machine, and a hair-dresser (!) the stocking-loom.

Still less will the popular hypothesis of heredity avail, for, though the champions of women's equality and rights argue as if men and women were two races existing independently side by side, every man was born of a woman, and every woman begotten of a man. Indeed the debt that great men have owed to their mothers is a favourite theme with their biographers, and it will be found that distinguished women have almost without exception inherited their talents from their fathers. This oblique transmission of intellect may be looked on as a law of heredity tending to the wider diffusion of genius, which would otherwise become the monopoly of certain privileged families.

A fact, the bearing of which on the practical side of the education question is of the utmost importance, is that while the transition from boyhood to manhood is gradual and spread over a number of years, the girl undergoes in about as many months a complete change in her sexual organisation and functions, on which, as on the greatest event of her life, her vital and nervous energies ought to be concentrated. Unfortunately this too often occurs just when the stress of examinations tends to divert these in other directions, at the risk of irreparable injury to her entire being.

The strain and pressure of close study and examinations for degrees or diplomas ought therefore to be deferred until a girl has passed through this critical period and arrived at maturity. This does not mean that her education should be neglected until then, for "education" in the proper sense of the word is the "drawing out" of the latent and potential faculties in the harmonious development of body and mind, so as to attain the *mens sana in corpore sano*. Though in this age of competition it may be unavoidable, I do not hesitate to assert that study under compulsion, and the exacting requirements of university degrees, especially of those which like the London B.A. demand simultaneous proficiency in a number of subjects, are ill-suited to the female constitution. So far as possible freedom and spontaneity should be the ruling principles of the education of a girl, her work, whether physical or mental, should be a pleasure though a duty, not a task, be guided by "her own sweet will" and by healthy emulation rather than by forced exertion. Indeed the best work achieved by women in the past has been thus undertaken after twenty years of age, often as the partners in their husbands' studies and pursuits, and in every sense a labour of love.

Cheap Dinners.—The provision of dinners, or of breakfasts and dinners, at the price of 1*d.* or 2*d.* would go far towards lessening the evils of "over-pressure" in the case of poor and

ill-fed children in elementary schools. It has been extensively tried in London by the Rev. Stephen Fuller, Mr. Fred. Mocatta, and Mr. Bousfield, who have found that where the number exceeds 250 daily it can be made to pay expenses.

Country Holidays for Poor Children in Towns.—Feeble children brought up in the poorer and crowded quarters of large towns derive marked and lasting benefit, physical and mental, from a sojourn of a few weeks in the country or by the sea during the summer holidays. They may either be boarded out in respectable families—as has been the practice in Copenhagen for more than thirty years, and has lately been undertaken in the East-end of London, under the auspices of the Rev. S. A. Barnett, of St. Jude's, Whitechapel—or what, though rather more costly, is infinitely better, sent out in so-called "Holiday Colonies," about fifteen or twenty in each party, under the leadership of a selected teacher of the same sex. This system presents moral and intellectual advantages which cannot be secured by the others. Holiday Colonies, which owe their origin to Pastor Bion, of Zurich, have during the last forty years spread to nearly every town of Germany, and to some in Italy and other countries, but have not yet been tried in England. I gave a full account of their organisation in a paper read at the Conference on School Hygiene, held in connection with the International Health Exhibition, and shall be very happy to afford all possible information on the subject.

Dormitories.—Not less than 800 cubic feet should be allowed for each boy, for the amount of ventilation necessary to keep a smaller space wholesome would certainly be found intolerable in cold weather. In summer the windows should be more or less open, the more the better, all night, and always opened so soon as the boys leave in the morning. They should be used for sleeping only, be without carpets, curtains, or vallances to the beds. The system of closed cubicles is to be condemned on sanitary and moral grounds, and doubly so when they are used as studies by day. The only tolerable form is when, by partitions six feet high, a degree of mutual privacy is allowed to older boys, the cubicle being open in front to the inspection of the master in charge. An indirect advantage, resulting from a sufficiency of

floor space, is the lessened risk of infection should a boy be sickening for some infectious disease. Six feet by twelve in a room twelve feet high gives 864 cubic feet, or 800 after deducting the space filled by the furniture, &c. The notion that children require less air space than adults is an erroneous one; the young and growing need the more abundant supply of pure air.

The beds should never be turned up or packed away during the day, but stripped so soon as they are vacated by the boys, and allowed to "air" for an hour before being again made, the interval being employed in removing slops, sweeping, &c.

Dormitories should always be on a side of the building fully exposed to the sun, the southern aspect is the best in every way, but where practicable there should be windows on opposite sides of the room.

Artificial lighting should be by ventilating burners on Siemens' principle, one or two of which might with advantage be left burning low all night.

Warming is rarely, if ever, requisite, if the site and buildings be fit for a school, but if really necessary it should be effected by some means combining ventilation, and on no account by lighting up gas burners to deteriorate the air.

A lavatory should be attached to each dormitory, with a number of "tip up" basins, and taps for hot and cold water of a kind that cannot be left running. There should also be baths of sufficient size or number as to allow of every boy having a daily morning's plunge, and a slop sink well glazed, trapped, and intercepted. Urinals are not allowable indoors, but a night water-closet should be provided on each floor, well ventilated, and not communicating with the dormitory.

Beds.—Iron bedsteads, three feet by six feet. Horse hair, or better still wire mattresses; blankets, not too many or too heavy; and cotton sheets, preferably those made somewhat thick, soft, and rough.

Punishments.—On those we can but make a few passing remarks. For corporal punishment administered with

discretion much is to be said, *i.e.*, in the case of boys, and for offences of a moral character. But boxing the ears, hitting the head, and the use of rulers, or hard bodies of any kind, cannot be too strongly condemned. Even caning the hand may do injury of a lasting nature to the tendons and joints. Really the older fashioned operation of caning the posterior region of the body was the safest and most appropriate.

Detention in the impure air of the school is objectionable, though in a well-ventilated room the tedium of sitting silent and unemployed may be a fit punishment for girls; but for boys or girls there is nothing so good as "extra drill," as now practised at Christ's Hospital, while the others are enjoying themselves at play. To the able medical officer, Dr. Alder Smith, is due the credit of the introduction of a system which conduces to the moral and physical improvement of the subjects of this mode of punishment. Tasks and impositions of all kinds do harm both physical and mental, depriving the pupils of air and exercise, giving a distaste for learning, and aggravating the evils of overwork.

Prevention of Infectious Diseases.—On this subject we cannot do much better than recommend the Code of Rules issued by the Association of Medical Officers of Schools,[1] and based on a paper read by Dr. Alder Smith at the Conference on School Hygiene, held in connection with the late International Health Exhibition.

All large boarding schools should be placed under the medical supervision of one, and only one, medical officer, who should have full control over all matters affecting the entrance into or departure from the school of all boys who have recently had, or who have been exposed to, infectious diseases of any kind; also over the whole arrangements for the isolation and treatment of such

[1] Published by Messrs. J. & A. Churchill, New Burlington Street. Price One Shilling.

cases, and matters of quarantine and disinfection. He should be responsible only to the governing body and head master, removable only by the same body that appoints the head master, and the rules that he may have drawn up or adopted, having been approved by the governing body, should not be over-ruled even by the head master himself.

A large school should have a good detached infirmary, to which all cases of illness should be sent, whether occurring in the school buildings or in the houses of the masters ; with at least 1000 cubic feet to each bed, and 2000 to those in the wards for infectious diseases, of which there should be two, with nurses' rooms, lavatories, laundry, and kitchen, completely isolated from those of the general infirmary.

In small schools this rule may be modified according to circumstances, but in the extreme case of being reduced to a single room, it should be at the top of the house, or better still, of some wing.

All boys on first admission to the school should be provided with a written statement of the infectious diseases that they have already had, and of which they are therefrom presumably insusceptible. Much needless anxiety, inconvenience, and perhaps interruption of studies, may thus be saved, in the event of those particular diseases breaking out in the school.

If during the holidays a scholar suffer from any infectious disease, or if he be exposed to such infection, though he may not take the disease, notice should be at once given to the school authorities, and he should not be readmitted until such time, and except under such conditions, as the medical officer may lay down. As a further security, no boy should, under any circumstances, be admitted or readmitted to the school without a certificate stating that he has not had, or been exposed to, any infectious disease within a certain prescribed period. If he have been merely exposed to infection, he may be

admitted after the expiration of the following quarantine periods, reckoning from the date of such exposure:—

Scarlatina, . .	8 days.	Chicken-pox, . .	18 days.
Diphtheria, . .	12 ,,	Small-pox, . .	18 ,,
Measles, . .	16 ,,	Mumps, . . .	21 ,,
German Measles, .	16 ,,	Whooping-Cough, .	21 ,,

and after thorough disinfection under the direction of the medical officer of the school, he being washed with some strong soap and hot water from head to foot, and his clothes changed, or subjected to disinfection in the oven. Disinfection at home must never be relied on. Day scholars require vigilant attention, as they often introduce infectious diseases into boarding schools. Boarders visiting friends may do the same, and when any such disease is epidemic it might be advisable to declare the whole town "out of bounds." Any case occurring in the families of the staff or servants should be at once removed to the hospital, and tradesmen required under penalty to inform the authorities of cases in their establishments, or in the houses of such of their servants as have any access to the school.

Neither the construction nor the internal administration of the school hospital comes within the scope of the present work.[1] Suffice it here to say that the most absolute isolation and separation of persons and things must be maintained, not only from the school, but between the common wards and those devoted to infectious diseases.

When a case has been taken from the school to the hospital, the masters, matrons, &c., should be privately informed of the nature of the disease, and of the symptoms attending its first invasion, and instructed to watch for such in all boys who have been in contact with

[1] No better models, however, could be found than the Cottage Hospitals for infectious diseases, described by Dr. Thorne-Thorne in the *Transactions of the Epidemiological Society*, N.S., vol. iv., 1884-5.

the patient, with a view to their removal before they shall have infected a third set of boys.

For disinfection, Lyon's, Reck's, or Thresh's apparatus is the best. Heat is the most efficient germicide. Corrosive sublimate in solutions of one part per 1000 is the best of chemical agents, or "Formalin," one part in twenty of water.

It is needless to insist on the immediate evacuation of the dormitory in which a case has appeared, and the thorough disinfection of the room, &c., by the solution of corrosive sublimate, rather than SO^2 or chlorine, as well as of the bedding in the oven or by sublimate washing.

A child who has had any infectious disease, and has been thoroughly disinfected together with his clothes and property, may be allowed to return to school after the following periods :—

Scarlatina.—Not less than eight weeks from the appearance of the rash, provided peeling have ceased, and the throat, ears, and nose be perfectly healthy. Six are insufficient, as I know from experience, having seen cases of infection after seven weeks, when all symptoms had entirely disappeared, and every possible cause except personal contact in kissing excluded. I would say eight or ten.

Measles and German Measles.—In three weeks, provided all desquamation and cough have ceased.

Smallpox and Chicken Pox.—A fortnight after the last scab has fallen off; the hair in the case of smallpox having been cut short, and scrubbed with soft soap and hot water.

Mumps.—Four weeks from the attack, if all swelling have disappeared.

Whooping Cough.—Six weeks from the recognition of the whoop, if the cough have entirely lost its spasmodic character ; or four, if all cough whatever have ceased.

Diphtheria.—In a month, if convalescence be complete,

there being no trace of sore throat, or discharge from nose, eyes, &c., or of albumen in the urine.

Ringworm.—When the whole scalp, carefully examined in a good light, shows no stumpy, broken hairs or scaly patches ; any suspicious spots having been examined microscopically.

Ophthalmia.—When there is no more discharge or granulation on the lids.

Though parents should be at once informed of the breaking out of infectious diseases, those at least of a dangerous nature, and though it might be difficult to retain a child against the wish of the parents, the danger of sending home any in whom such disease may be latent is so great that it should be, if possible, avoided. It would mostly be easy to satisfy reasonable parents that where the code of regulations to which we have referred is adopted, the danger to the pupils is reduced to a minimum, whereas a child returning to mix with brothers and sisters may communicate the disease to them. To a boy of fourteen, scarlatina, for example, is most likely to prove a trifling illness, but if he give it to his brothers or sisters of two to six years of age, one or more may probably die.

Indeed, the only circumstances which in my opinion can justify the breaking-up of a school are when the disease, as typhoid or diphtheria, is evidently due to some sanitary defect, the nature of which is unknown, and the discovery of which demands such opening up of drains, &c., or alterations as can only be effected in the absence of the inmates of the buildings. Otherwise it inevitably leads to a wide spread of disease, and perhaps to much loss of life. The closure of elementary schools, though provided for by the Education Department after consultation with the local Medical Officer of Health, is a procedure of doubtful utility, save at the commencement of an epidemic, when, however, it is not likely to be demanded or even suggested, and worse than useless

when the disease has become firmly rooted and widespread. The children are merely associated in the streets instead of in the school, and little is gained thereby. It is, however, but fair to refer to Dr. S. Cameron's success in the systematic closure of the Jarrow Schools so soon as cases of measles appeared in each from six or more separate houses or centres. (See his exhaustive papers in the *Trans. Epid. Soc.* 1891–2.) Measles, scarlatina, and whooping cough are constantly communicated in school, but the better means of preventing this is to require notification of all cases by the parents to the sanitary authority, and by the authority to the teacher, that all children from infected houses may be at once excluded from the school. This is already the practice in some places, where the teachers also report the absence of children for more than one or two days, that the sanitary authority may make inquiry as to the cause. Such enforced absence does not now count against the children's presentation at examinations. Return to school should be allowed only after all danger is past, and the teachers should be instructed to recognise the earliest symptoms of disease, as well as those of incomplete recovery, and to refer all suspected children to a medical man selected by the managers as their medical inspector or adviser. Measles and diphtheria are mostly communicated in the initial stage; scarlatina during the consecutive stage of peeling; and whooping cough either before the characteristic spasmodic cough is developed, or by cases in which it never acquires such a character as to be recognised by any but an expert.

The code provided for the allowance of an "average attendance" being credited to the whole of the children excluded during the legal closure on account of epidemics, with a view to the award of the grant under that head, but I persistently urged that the same concession should be made (so long as the grant is dependent *inter alia* on the average attendance) on account of individual children excluded in consequence of their

suffering from, or being in the same house with cases of infectious disease, to avoid the spread of the disease in the school by their means, and as an act of justice to the teacher in voluntary schools in which his salary largely depends on the amount of grant earned. This was at last conceded by section 101* in the code of 1899.

Summary of Chapter XVII.

The cubic space per head in schools is rarely sufficient to maintain a reasonable purity of the air without draughts. The 120 or 130 cubic feet in elementary schools is grossly inadequate, for if the standard be put so low as 0·8 cubic feet of total CO^2, *i.e.*, 0·4 of the respiratory, and the air changed six times in the hour, which would be intolerable unless the incoming air were warmed, 500 feet would be needed. In Canada 250 is required and the air is warmed before admission. Light should be ample, though the direct rays of the sun must be kept from the eyes. There is no harm in "cross lighting" provided that from the left is the stronger, and windows facing the desks should be dimmed. Electric light is far preferable to gas, which adds to the impurity of the air, but, like that of the sun, it should not fall on the eyes. Short sight is often hereditary, but it is produced by insufficient light and small type, &c., which should be avoided, especially for the younger children, and other defects of sight as hypermetropia and astigmatism should be looked for and treated by suitable glasses.

There can be no sufficient illumination unless the light come from the sky, and fall on the floor at an angle not less than 25°, for its intensity diminishes inversely as the square of the area over which it is distributed.

Ill-contrived desks and seats lead to faulty positions and tend to spinal curvatures.

A vigilant watch should be maintained in respect of infectious diseases, especially the appearance of sore throats, however apparently mild. Such children must be sent home or referred to a medical man ; the cause of absence of any child ascertained, and if, on account of infectious disease, no others from the same house be allowed to attend, nor should a child be readmitted so long as there is any danger of infection. Rules and information on the subjects of incubation, persistence of infectivity, &c., should be drawn up and their observance insisted on. By these means closure of a school might often be avoided.

QUESTIONS ON CHAPTER XVII

1. What is the best position for writing? What are the advantages of such a position? 1887,A.

2. Describe, stating your reasons, the school furniture you consider best adapted for young children. 1890,A.

3. How is short sight produced in school-children? What measures are necessary to prevent it in schools? 1891,A.

4. How would you ventilate a school-room, and how much space would you allow to each pupil? 1896,A.

5. Describe fully the chief points to be considered in the construction of school-rooms. 1900,H. I.

6. The Code requires 8 feet super and 80 cubic, the London School Board 12 and 130 respectively for each child. The Education Board of Ontario 250 cubic feet. Criticise these allowances, and show how many times an hour the air must be renewed to maintain the permissible degree of impurity, or what degree is compatible without intolerable draughts under each allowance. Do children require less than adults?

7. Why should the light come chiefly if not wholly from the left? If that from the left be the stronger, so that the hand does not cast a shadow, is there any harm from "cross-lighting"?

8. Discuss the effect of light from the left, the right, the front and the back.

9. What is the effect of the angle of incidence on the intensity of the illumination, and how does "cross-lighting" affect this?

10. Where should maps be hung and black-boards placed? In what positions are clear glass windows without blinds inadmissible?

11. What would be an ideal system of artificial lighting of schools? What advantages other than greater intensity does the electric light possess over gas?

12. What is the difference between the lower and upper floors as regards the sufficiency of natural illumination when there are houses on the further side of the street?

13. What precautions as to exclusion of children likely to spread infection are sanctioned by the Education Department with a view to avert the necessity for closure of a Public Elementary School?

14. Describe the best arrangements for school dormitories.

15. How is ophthalmia caused and spread in schools? What precautions should be taken?

16. What steps should be taken as to isolation and quarantine of "suspects" and "contacts" on the outbreak of infectious disease in schools? What further procedure is advisable in the cases of small-pox and of diphtheria?

CHAPTER XVIII

Health in the Workshop

In the chapter on Statistics and Demography I shall discuss the relation between occupation and mortality, as well as the fallacies incident thereto and based on the mean age at death.

I shall here notice only those trades the conditions of which, whether preventible or not, are specially injurious to the health of those engaged therein, with the causes of such unhealthiness: and those which are a source of annoyance or injury to the health of the surrounding population, "offensive" trades as they are called in the Public Health Acts.

The terms offensive and unhealthy are not, however, synonymous, for the effluvia may be an annoyance to the sense of smell and interfere with the enjoyment of persons living in the neighbourhood without being actually hurtful, and the converse may sometimes be true.

Thus there is little or no evidence to prove that the fumes from the partial combustion of organic matter emanating from fat and tallow boiling, blood boiling and drying, soap boiling, and similar works, however offensive, exert any deleterious influence on the public health, and the same may be said of brick kilns and gas works. Even slaughter houses and knackers' yards, if well arranged and properly conducted are offensive rather to the sentiments than to the senses, and need not be so at all to the health; while on the other hand lime kilns, cement works, and charcoal burning, were it not that they are of necessity located in the open country, and indeed any processes emitting

large quantities of CO^2 would be dangerous to health, albeit unattended by any odour whatever.

The circumstances which tend to render certain occupations hurtful or inimical to health are: (1) Prolonged occupation of close, crowded or ill-ventilated rooms, especially if aggravated by cramped postures and late hours.

Under this head come printing houses, though great improvement has been made of late, but much printing is necessarily carried on at night, and draughts are inadmissible. Tailoring, dressmaking, fur-cutting, &c., and shoe-making, especially when followed at home or in "sweaters' dens"; and it is much to be desired that some form of tables could be designed to obviate the cramped postures affected by tailors and shoemakers at their work, inducing dyspepsia and phthisis.

(2) Exposure to cold winds and rain, especially when there is no demand for muscular exercise.

Thus cab and omnibus drivers, carmen, railway engine drivers, and stokers suffer from rheumatism, and respiratory affections of a catarrhal kind.

(3) Exposure to excessive heat, to steam, and still more to sudden changes of temperature.

Metal founders, glass blowers, workers in pottery, bakers, &c., men in gas works, &c., suffer in this way; and in cotton weaving sheds the air is often charged with steam, which saturates the clothing of the operatives, who suffer from severe chills on going into the outer air.

(4) Inhalation of dust whether metallic, mineral, or organic, and whether acting mechanically or chemically on the mucous membranes of the respiratory passages. The consequences are, as Hirt has pointed out, every form of pulmonary irritation and phthisis except tubercular, to which they are not more prone than others, and less so than those who work in ill-ventilated rooms or crowded workshops. These diseases Hirt designates collectively as *pneumokoniasis*.

The consequences of the inhalation of dust depend on the character of the particles as regards the ease with which they are removed by the action of the cilia, their septicity, angularity, and chemical action.

Thus animal dust, as in poudrette works, is the most poisonous, and the amorphous inert mineral dusts the least hurtful. Worst of all are those which act as caustics or chemical irritants, as bichromate of potash, and lime ; and most innocent is pure carbon, as lamp black.

The following is a rough enumeration of the chief or representative industries of each kind :—

Animal Dust, Septic.—Artificial manure works.

Animal Dust, Fibrous.—Shoddy mills, wool carding and weaving, and all factories for working wool, hair, fur, or silk. Bristle dressing and brush making give rise to an extremely irritating dust.

Animal Dust, Amorphous.—Bone mills ; ivory, bone, and horn turning ; and mother of pearl polishing.

Vegetable Dust, Fibrous.—All industries in which cotton, flax, hemp, jute, or wood wool are employed in the dry state, and especially the processes known as preparing, stripping, hackling, carding and blowing. Flax and hemp give a dust more irritating and difficult to get rid of than cotton. Jute is often rendered less dusty by being saturated with oil. In the weaving of cotton and linen goods a dressing of lime with size and starch is much used, adding to the other a large quantity of irritating mineral dust.

Vegetable Dust, Amorphous.—Flour mills of all kinds and the grinding of snuff, starch, and drugs. The dusts from pepper, mustard, ipecacuanha, tobacco, &c., are specially irritating and may be poisonous by absorption, while that from flour is by far the most innocent.

Chemical Dust, irritant and poisonous.—Bleaching powder, bichromate of potash, white lead and chemical manure manufacture, with the grinding and using of chemicals, pigments, plasters, cements, &c.

Mechanical irritants, Metallic.—Dust from dry grinding and polishing of knives, tools, and cutlery, files, needles, and metalwork generally, also the use of "bronze powders," &c.

Mechanical irritants, Mineral.—Dust from stone and marble working, millstone and grindstone making, grinding and crushing glass, emery, cements, &c., and scouring and finishing pottery. In the last and in the use of the sandblast for cutting glass, and the manufacture of glass papers, the sharp particles are painfully irritating. Then there is the dust in mines, especially collieries,

and lastly soot and lamp black (though the latter is usually made from oil) in the manufacture of printers' ink.

Gases and Vapours.—Miners are exposed to carbonic dioxide (CO^2) and marsh gas (CH_4), or "choke and fire damp," and to the products of explosion of blasting powders, &c.; carbonic acid is also evolved in lime, cement, and charcoal burning, and mineral water works.

Ammonia, ammonium sulphide, hydric sulphide (H_2S), hydrochloric acid, chlorine, sulphurous acid, &c.; in alkali, chemical and vitriol works, and in the manufacture of bleaching powder and in gas works, and with carbonic acid in chemical manure works.

Arsenical vapours are produced in roasting ores.

Zinc fumes in brass founding give rise to the so-called brass founders' ague.

Bisulphide of carbon is largely used in indiarubber works, and coal-naphtha, benzol, &c., in these, and in gutta percha works, &c.

Mercurial vapours are sometimes, but now rarely, produced in special cases.

Offensive and more or less *unwholesome* effluvia are given off in fat, tallow, candle, soap, blood, bone, and tripe boiling, in tanneries, and fellmongers' yards, glue and size works, superphosphate, fish manure and similar manufactures, in sewers and sewage works, and scavenging generally.

In hair and wool sorting, and in handling hides there is the risk of inoculation with septic material with the specific diseases of cattle communicable to man, as anthrax or glanders, and in rag-sorting the like danger of infection with human specific disease.

Poisons introduced by absorption, ingestion, or inhalation.

Lead in white lead manufacture, house painting, constant handling of pewter, &c., and in plumbing; arsenic, cadmium, mercury, lead, antimony, &c., in colour grinding and mixing, and in "bronzing" and "gold" printing ("bronze powder" being a mixture of metallic copper, sulphate of tin, and antimony), in artificial flower making, wall paper printing, enamelling cards (French "chalk" being really carbonate of lead), enamelling tin plate, &c., in porcelain glazing, mirror silvering, match-making, and hat-making.

Through the operation of the Factory Acts and the vigilance of the inspectors, great improvements have been and are being continually made in every department of industry.

Increased cubic space, better ventilation, screens, splash boards, fans to carry dust from the operator and for extracting

the dust, &c., from the air of the room, improved apparatus doing mechanically in closed chambers what was formerly done by hand, and otherwise superseding manual labour, substitution of non-poisonous pigments for the dangerous ones formerly in use, prohibition of meals in workshop, and provision of conveniences for ablution, the substitution of red or amorphous for ordinary phosphorus in matches, disinfection by steam of wool, hair, and rags before sorting, "mechanical stokers," waterproof dresses and respirators, though these last are inconvenient and not liked : by such and similar means the dangers have been greatly reduced if not wholly removed.

But a few are still only partially improved, *e.g.*, the white lead manufacture, in which so long as the "stack" or "Dutch" process holds its ground no precautions seem to be of any avail in preventing the inevitable consequences of colic, palsy, or convulsions, at least among those who are exposed to the dust. Nothing holds out any hope of remedy but some totally different procedure, as that of Professor E. V. Gardner, in which the whole manufacture is conducted in closed chambers, though the "French" process of precipitation from a solution is far less dusty and dangerous, and the "Dutch" might be rendered comparatively safe by substituting machinery for hand labour in stripping the plates, and in carrying the pans to the oven.

Symptoms of lead poisoning or plumbism. Obstinate constipation and colic, relieved only by large doses of Epsom salts; lead palsy, often called "wrist drop" from the paralysis of the extensors, or muscles of the back of the arm and hand being the earliest and most marked, and epileptiform convulsions : the palsy will generally yield to prolonged treatment with iodide of potassium, but the first convulsion is as a rule fatal, and may or may not be preceded by other symptoms. The "blue line" on the gums, though universal is not essential, a certain amount of "tartar" on the teeth being requisite for its production.

Mines are for the most part better ventilated, and the sanitary arrangements of mills and factories as well as of workshops greatly improved, while legislative restrictions on the hours of work for women, young persons, and children, have done much to raise the moral, social, and physical conditions of the industrial classes. But the law has as yet failed to reach the sweater's den, the quasi-domestic workshops and dwellings of the poor, in which so much contract outfitters' slop and "season" work is still carried on, or to effect any material change for the better in the "home work" of the nail, bolt, and chain makers and file grinders of the black country.

Summary of Chapter XVIII.

Offensive trades, as tallow boiling, are not necessarily unhealthy, though they may constitute nuisances and are on that ground brought under special provisions of the Public Health Acts. Nor are others which are dangerous to life or limb and as such come under the cognisance of the Factory Inspector.

The circumstances rendering an occupation injurious to health are (1) Defective ventilation and overcrowding, especially if aggravated by nightwork with gaslights, and in some still further by cramped postures. These are conducive to general ill health and feeble power of resistance to disease, above all to tubercular phthisis. Such are tailoring, shoemaking, fur cutting, &c., especially when carried on in "sweaters' dens," and the older class of printing houses where much work is done at night.

(2) Exposure to cold and wet without much muscular exercise, and with the inducement to indulgence in alcohol.

(3) Exposure to excessive heat, steam, and sudden changes of temperature; such are foundry work, glass blowing, pottery work, baking &c.

(4) Inhalation of dust, metallic, mineral or organic, whether acting simply as mechanical irritants, or involving the absorption or swallowing of poisons.

Among the former are the grinding of cutlery, working in stone, grinding cements, working in bone, bristles, and all textile industries, as well as flour mills and drug grinding. Chemical and poisonous dusts are bleaching powder, white and red lead, bichromate of potash, &c.

Poisons absorbed are phosphorus, mercury, arsenic, and noxious fumes, vapours and gases, as chlorine, sulphur, zinc fumes, vapours of carbon bisulphide, &c.

White lead manufactures, glazing pottery, match making, and a few others are especially dangerous.

Anthrax is occasionally contracted by handling infectious hairs or hides.

QUESTIONS ON CHAPTERS XVIII AND XIX

1. What trade manufacturing processes are likely to give rise to diseases of the lungs? Explain their deleterious action and state the means of prevention to be adopted. 1892, H.

2. How do manufactures directly affect the health of those engaged in them? Give a list of four of the most objectionable

in the order of their injuriousness and state the means to be used in order to prevent their evil effects on the operatives in at least two of them. 1894, H.

3. What kinds of dust are the most, and which the least hurtful? How do the former act? In what do their effects appear, and how do they conduce to tuberculosis?

4. Give the chief trades, the ill effects of which result from the inhalation or absorption of poisons.

5. What are the chief symptoms of lead poisoning, and in what trades is it of most frequent occurrence? In which may it be avoided by the workmen themselves, and in which not? What precautions or procedures are to be recommended in the manufacture of white lead?

6. Why do the coal miners of Durham suffer far less from tubercular phthisis than those of other districts? and why is it most prevalent among Cornish tin miners?

7. What is the most characteristic symptom of phosphorus poisoning? How may the danger be minimised in match factories by modifications of the process and by medical inspection of the workpeople?

8. In what manufactures do the operatives suffer most from exposure to heat and steam?

9. In what manufactures is arsenical poisoning most frequent, and what are the usual symptoms?

10. What special dangers to health, and what forms of disease are associated with the following industries: (*a*) rag and wool sorting; (*b*) cotton cloth manufacture; (*c*) file making? What are the best means of obviating these dangers? 1898, H. II.

11. Discuss the influence of the employment of married women in factories on infant mortality.

12. Mention three *offensive* trades. Describe in each case what it is that causes or is likely to cause offence, and what is the best means of dealing with it. 1898, H. II.

13. State the general provisions of the statute law for the abatement of the smoke nuisance. 1898, H. II.

14. Distinguish between offensive and unhealthy trades, giving examples of the former that are not hurtful to the persons engaged in them.

15. Which classes of the community enjoy the greatest exemption from phthisis and respiratory diseases?

PART V

DEMOGRAPHY

CHAPTER XIX

Statistics of Population

It is a frequent remark of incredulity or indifference that figures may be made to prove anything, and so they may if ignorantly or fraudulently manipulated. It is a sufficient answer that without figures one can prove nothing. Most persons, too, draw their conclusions from their own experience and from the facts or phenomena that have come under their notice, or which from their exceptional character, or their falling in with their preconceived opinions, have attracted their attention.

Sound conclusions in respect of social phenomena and the conditions of large communities can only be arrived at by the absolutely impartial contemplation of the statistics of populations, their numbers, increase or decrease, birth, death, and marriage rates, constitution as regards sex, age, employment, distribution, movements, &c. &c., over sufficiently long periods, and it is no exaggeration to say that on demography, as involving the first principles, and supplying the fundamental data, all social legislation and administration, all sanitary reform and philanthropic endeavours must be based.

Besides, since like can only be fairly compared with like, and the conditions of two groups of phenomena are very rarely identical, crude recorded results are among the most fallacious of data, unless the "facts" are "corrected" on rigidly scientific methods.

The neglect to take into consideration each and all of

these facts and phenomena, as well as every disturbing or modifying influence whatever, will inevitably lead to erroneous conclusions. It is, indeed, rare to meet with a report on the "vital statistics" of a community, or an examination of the sanitary conditions of any class, which is not more or less falsified by error; and it is a fact that the most obvious inferences from any given data are rarely correct, and may be the very reverse.

Thus the population of the most rapidly-growing towns may be slowly dying out, and the healthier may show the higher recorded death rate, short-lived communities may boast the largest proportion of old people, the mean age at death may be low in the healthiest occupations, and death at advanced age be no evidence of conditions favourable to longevity. But it would be a great error to conclude that no trustworthy conclusions can be drawn, for it is not difficult for an expert to eliminate the several sources of error, or at least to approximately estimate their influence.

Population

The first essential condition of all statistics is a knowledge of the number of persons in a community, and second only in importance is the constitution of the population, *i.e.*, the absolute and relative numbers of individuals of either sex, and of each age, or, for practical purposes, of persons living within certain limits of age or age periods. These facts are accurately known only in the census years, estimates having to be made for those intervening.

The interval of ten years is, however, too long, and it is to be hoped that Parliament, if unwilling to incur the expense of a complete census every five years, would sanction an enumeration with at least a statement of sex and age. We cannot urge the exigencies of military conscription, or considerations of such development as present themselves in our Canadian and Australian dependencies, but the claims of the public health ought to be held as no less weighty.

Estimated Populations

As a basis for the calculation of birth and death rates for the intervening years, estimates are made on the as-

sumption that the population continues to increase at the same rate as the last census showed it to have done in the preceding decennium, which, however, is found by experience to hold good very seldom indeed.

The Registrar-General thus calculates the estimated population of each year for the metropolis and the larger towns, as well as for the whole country, on the theoretically accurate basis of an increase in geometrical progression; but for practical purposes this is a needless refinement, since the error involved in the employment of the simpler arithmetical progression is as a rule less than that inseparable from the assumption of uniform increase of any kind.

If we content ourselves with A.P. the process is as follows.

Let P = present population (assumed)
P' = population at last census
P'' = population at preceding census.
I = Annual increase $= \dfrac{P'-P''}{10}$
N = Number of years since last census.

If we add $\frac{1}{4}I$ or $\frac{1}{4}$ for the three months between the date of the census, viz., the Sunday nearest to April 1, and the middle of the year, then

$$P = P' + (n+\tfrac{1}{4})\left(\frac{P'-P''}{10}\right) = P' + I\,(n+\tfrac{1}{4})$$

Thus pop. in 1891 = 36000; in 1881 = 32000

$$I = \frac{36000-32000}{10} = 400 \text{ and}$$

Estimated pop. in middle of 1885, when $N=4$

$$P = 36000 + 400(4+\tfrac{1}{4}) = 37{,}700.$$

By the Registrar-General's method the estimated population is somewhat higher, in this case 37,848.

To estimate the population for the middle of the year of the census, which is taken at the end of the first quarter, he adds to the logarithm of the census population one-fourth of the logarithm of the annual increase during the preceding ten years; and for each succeeding year the logarithm, twice the logarithm of annual increase, and so on, is added to the population thus obtained. The sum is the logarithm of the estimated population for the middle of any given year.

Or using the same expressions and formulæ as in calculating compound interest, viz., r = annual rate of increase per unit, and

$(1+r)^n$ = the pop. at the end of the n^{th} year from the last enumeration.

Substituting R for $(1+r)$, $P = P'(1+r)^n = P'R^n$

To find the value of r or R taking the population P' and P'' as before.

$P' = P''(1+r)^n = P''R^n$ and since at the end of the ninth year $n = 10$ $P' = P''R^{10}$ and $\log P' = \log P'' + 10 \log R$ whence $10 \log R = \log P' - \log P''$ and $\log R = \dfrac{\log P' - \log P''}{10}$ from which R is easily obtained by the Tables.

Ex. In the example given above $P'' = 32000$, $P' = 36000$ and P = present population n, i.e., $4\frac{1}{4}$ years since the last census.

Hence $\log P' = \log 36000 = 4{\cdot}556{,}303$ and $\log P'' = \log 32 = 4{\cdot}506{,}150$; $\log P' - \log P'' = 0{\cdot}051{,}153$ and $\dfrac{\log P' - \log P''}{10} = 0{\cdot}005{,}115$. But $(1+r) = R = 1{\cdot}0118$ from the Tables and $\log R = \log 1{\cdot}0118 = 0{\cdot}005715$ and $n = 4\frac{1}{4} = \dfrac{17}{4}$ years.

$$\begin{aligned} \text{Log } P &= \log P' + w \log R. \\ &= 4{\cdot}556{,}203 + \frac{17}{4}0 \times {\cdot}005715 \\ &= 4{\cdot}556303 + 0{\cdot}021{,}739 \\ &= 4{\cdot}578{,}042. \end{aligned}$$

and from the tables of logarithm $P = 37{,}848$ instead of $37{,}700$ by the older method.

Such is the procedure followed in the office of the Registrar-General for estimating the population for the years following the census, but the next decennial enumeration almost always reveals serious errors, of excess or defect, and often such as to falsify the conclusions arrived at during the latter half of the interval as to the improvement or deterioration of the public health, since, if the assumed population differ from the true one by no more than 10 per cent., an assumed death rate of 24 per 1000 will represent one of 21·6 or 26·4, as the case may be, and far greater discrepancies are of frequent occurrence.

Thus in 1871 it was found that the population of Gosport had been over-estimated by 33 per cent., and that of Cambridge under-estimated by 16 per cent., consequently the former had

appeared healthier and the latter less healthy than it really was, the death rates differing, not by 12 per cent., as had been imagined, but by 0·2 only.

In 1881 the populations of Hampstead, Paddington, and Kensington were found to have been over estimated by 20, 23·3, and 26·3 respectively; the apparent death-rate of 15 in the last-named having represented a true rate of 18·75.

But in 1891 the disillusions were even more striking. The population of London (Registrar-General's or the County of London) was estimated at 4,441,993, but found to be 4,221,452, or less by nearly a quarter of a million. Indeed, the rate of increase in all of the thirty-one large towns had been much less in the last than in the preceding decennium, falling in Nottingham from 34·3 per cent. to 13·6, in Hull from 26·5 to 10·9, in Salford from 41·2 to 12·4, and in Liverpool from 12·0 to a decrease of 6·2. The calculated death-rates were therefore all too low, in the case of Salford as 3 : 4 !

Some local sanitary authorities endeavour to check the estimates based on the untenable assumption of uniform increase by means which, though unauthorised and equally conjectural, are not without a certain value, provided due regard be had to the character of the population. Perhaps that most generally adopted, on account of its apparent simplicity, is, having ascertained from the last census the number of persons to a house, and assuming the density to remain constant, to calculate the population for each subsequent year from the number of inhabited houses as shown by the books of the rate collectors. But the new houses may be of a different class, and tenanted by more or fewer families, while there is a constant sub-division of existing houses into "tenements" side by side with the erection of new ones. Besides, the introduction of block dwellings of all classes presents a serious difficulty unless each several suite of rooms be reckoned as a separate "dwelling."

The fact is that the growth of towns is not so much a question of the excess of births over deaths, like that of the nation as a whole, as it is of movements and distribution of the inhabitants, *i.e.*, of internal migration, and is mainly determined by the fluctuations of trade, the rise or decline of local industries, and the caprices of fashion.

Dr. Newsholme, when one of the Medical Officers of Health for Wandsworth, believing immigration to exert a less influence on the constitution than on the numbers of a population, the families attracted to a town being mostly of the same character as the older residents, suggested another check on the official estimate, based on the assumption of a uniformity in the birth rate. Thus the population of Wandsworth having in 1861 been 70,403, and in 1871, 125,050, it was estimated in 1881 by the Registrar-General's method to be 221,093. But in 1872–81 the mean birth rate had been 35·68 per 1,000, and in 1881 the actual number of births was 7,582; therefore, assuming these to represent a birth rate of 35·68 per 1,000, the population would have been $\frac{7,582 \times 1,000}{35 \cdot 68} = 212,500$. The census in April, 1881, gave 210,434, and adding to this for the quarter to the middle of the year one-fourth of the annual increase, or $\frac{8000}{4}$, the sum, 212,434, was almost identical with his estimate, though less than that of the Registrar-General by 10,500. (*Vital Statistics*, Dr. Newsholme.)

In the case of seaside and other health resorts, it is practically impossible to form a correct, that is a satisfactory, estimate of the population, as a basis for the calculation of the death rate. In the "season," which may or may not coincide with the month of the census, the population is swollen by an influx of visitors, amounting perhaps to 20 or 30 per cent. of the whole, who may consist chiefly of pleasure-seekers, or of invalids, many of whom come only to die. The local authorities will generally exclude these deaths from their reports, but are not so ready to accept the permanent population only on which to reckon their death rates. In fact all so-called "correction," except that to be described, is little, if at all, better than "jugglery."

Definition of Terms Employed in Vital Statistics.

$$\text{Mean age at death} = \frac{\text{Sum of ages at death.}}{\text{Number of deaths.}}$$

$$\text{Mean age of the living} = \frac{\text{Sum of ages at census.}}{\text{Number of persons living.}}$$

$$\text{Mean duration of life} = \frac{\text{Number of persons living.}}{\text{Number of deaths in a year.}}$$

Probable duration of life or expectation at birth = age

at which a number, say 1,000,000, is reduced to one-half.

This is not the same as the mean age at death, for in two communities one in forty may die annually, *i.e.*, 25 per 1,000; but in one the deaths may be mostly those of infants, the adults reaching a good old age; in the other few may attain a great age though the infant mortality be low. Natural increase = excess of births over deaths —in 1880-1 = 1·52 for England and Wales. The rule given for finding the mean duration of life is true only of a stationary population, *i.e.*, one in which the births just balance the deaths, a condition rarely met with in this country, though approached in France, where the apparent increase of the population is almost wholly due to the immigration of foreigners, and their greater fertility.

For normal, *i.e.*, growing populations, Dr. Bristowe has proposed a formula which allows for the natural increase through the addition of new members of the community by excess of births over deaths, and would be equally applicable to a population decreasing by excess of deaths over births, but does not, as indeed no formula can, take cognizance of adult immigration, still less of the "floating" population, which in many places forms no small proportion of the whole. His formula is as follows:—

Let B = birth rate, D = death rate, and R = rate of annual increase of population.

$$\frac{\text{Log. B} - \text{Log D}}{\text{Log. }(1+\text{R})} = \text{Log of mean duration of life.}$$

Thus with our present mean birth rate of 35 per 1,000, Dr. Richardson's Utopian death rate of 4 to 5 per 1,000 would imply a mean duration of life of sixty-five years, not, as would at first sight appear, of 200 to 250 years. See paper by Dr. Bristowe in St. Thomas's Hospital Reports, 1876.

This formula applied to the nation as a whole gives results which, neglecting the almost inappreciable influence of emigration, and still more so of immigration, may be accepted as correct, but it is misleading when applied to local populations.

e.g. in the case of Mayfair, a sub-district of St. George's, Hanover Square, it gives a mean lifetime of 104·9 years! *Quod est absurdum.* But the abnormal constitution of the local population may be inferred from the fact that the crude death rate is only 10·08 and the birth-rate 8·95.

Dr. Rumsey proposed as a test of healthiness what he called lines of vitality and of mortality, or the mean ages of the living and the dying. In healthy districts the line of mortality is the higher, in unhealthy that of vitality. Thus he found in Herefordshire vitality = 28½ years, mortality = 38½; but in Liverpool vitality = 25, mortality = 17½, *i.e.*, in the former people lived longer; in the latter numbers died early. But immigration disturbs such calculations. Even in the rural parts of Surrey 24 per cent. of the population were immigrants.

Correction of Death Rate

That young children and old persons are more liable to die than those in the full vigour of youth and early adult life, is so obvious that to insist on the influence which a preponderance of individuals within one or other of these periods must exert on the general death rate would seem superfluous, were it not that crude death rates are constantly appealed to if apparently favourable, or indefinitely discounted and explained away if the reverse.

It is not too much to say that death rates calculated on the gross population are practically worthless as evidence of the sanitary conditions of communities less than entire nations, and for comparing these if there is much difference in their birth rates, calculated not on the gross population, but on the number of married or of marriageable females of productive age.

The "corrected" death rate of a town is the death rate as it would be under existing conditions if the numbers of persons of either sex and at each age period bore the same proportion to the whole as they do in the population of the entire country.

The data for calculating these rates are—(1) the normal

constitution of the population according to age and sex in the country at large; (2) the corresponding constitution of the local population in question; (3) the local death rate per 1,000 of either sex and at each age period; and (4), for comparison, the same for the general population.

The "standard" death rate is that which a given population would present if, constituted as it is, the mortality for age and sex were neither greater nor less than that of the general population. If the health of the town be above the average, the "standard" death rate will be higher than the corrected, and if worse it will be lower.

The "factor for correction" is the ratio between the "standard" rates of the general and local populations, taking the former as unity, and will be less than unity where the proportion of persons at ages of high mortality is excessive, and greater than unity where, as is the case in all the large towns of England except Norwich and Plymouth, the effect of immigration is to give a preponderance to young adults, whose low mortality makes that of the community appear lower than it really is.

The Registrar-General provides these details for thirty-four towns only, but the factor and the "corrected" death rate can be easily worked out, as well as the "standard" rate and the "comparative mortality," from the age and sex constitution as ascertained by the census.

To do so, taking the numbers of persons living of each sex and age period, calculate what the several mortalities would be were the rates the same as those for the general population. Adding these we have the standard mortality, and from it obtain the standard death rate, and dividing the death rate of the whole country by this, we obtain the "factor."

The "recorded" death rate multiplied by this factor gives the "corrected" rate, the only true indication of the local health.

33 Towns.	Population estimated to middle of 1898.	Comparative mortality figure 1898.	Recorded Death-rate 1898.	Corrected Death-rate 1898.	Standard Death-rate 1898.	Factor for Correction, 1891.	Birth-rate 1898.	Deaths of Infants to 1000 Births.	
								1898.	1888-97.
Croydon	124,421	824	13·89	14·48	18·37	1·0424	25·4	150	128
Cardiff	177,770	941	14·82	16·54	17·16	1·1159	31·1	158	160
West Ham	286,654	945	15·41	16·62	17·75	1·0788	30·6	170	154
Portsmouth	186,618	948	16·30	16·67	18·73	1·0224	26·7	156	150
Brighton	122,310	973	16·91	17·10	18·94	1·0110	24·8	181	148
Bristol	316,900	1,015	17·20	17·85	18·33	1·0379	28·6	164	144
Norwich	111,699	1,033	18·96	18·16	19·99	0·9579	29·9	192	175
Leicester	208,662	1,046	16·93	18·38	17·64	1·0855	29·6	191	199
Huddersfield	102,454	1,053	15·92	18·51	16·47	1·1627	22·5	153	158
Derby	104,384	1,055	16·82	18·55	17·36	1·1031	27·4	169	152
Burnley	109,546	1,065	16·30	18·72	16·67	1·1487	27·1	195	209
Plymouth	99,136	1,080	19·54	18·99	19·70	0·9720	29·7	170	168
Nottingham	236,137	1,081	17·67	19·00	17·81	1·0752	28·9	178	174
Birkenhead	113,189	1,090	17·44	19·17	17·42	1·0993	30·4	186	162
Hull	229,887	1,097	18·36	19·29	18·23	1·0504	33·4	182	173
Halifax	96,729	1,131	17·87	19·89	17·20	1·1133	22·9	163	158

London . . .	**4,504,766**	**1,133**	**18·68**	**19·91**	**17·97**	**1·0656**	**29·5**	**167**	**155**
Oldham . . .	148,288	1,145	17·58	20·13	16·72	1·1453	25·3	175	178
Bradford . . .	233,737	1,146	17·60	20·14	16·73	1·1446	24·0	185	171
Swansea . . .	102,001	1,154	18·57	20·29	17·53	1·0924	28·9	184	157
Blackburn . .	133,228	1,179	18·45	20·72	17·05	1·1231	27·1	206	201
Preston	116,356	1,210	19·35	21·27	17·42	1·1993	31·0	225	234
Leeds	416,618	1,211	19·21	21·29	17·28	1·1082	31·2	182	178
Bolton	122,495	1,249	19·38	21·96	16·90	1·1331	30·9	168	179
Birmingham . .	510,343	1,257	20·00	22·10	17·33	1·1050	34·0	191	180
Gateshead . .	103,775	1,259	20·61	22·14	17·83	1·0740	35·5	208	166
Wolverhampton	88,051	1,266	21·27	22·26	18·30	1·0464	35·8	200	188
Sheffield . . .	356,478	1,280	20·24	22·51	17·22	1·1120	33·9	195	180
Newcastle . . .	223,021	1,327	21·42	23·53	17·58	1·0892	31·7	190	167
Sunderland . .	143,849	1,351	22·63	23·75	18·25	1·0493	35·4	202	169
Manchester . .	539,078	1,411	21·89	24·80	16·90	1·1331	32·7	197	185
Salford	215,702	1,452	22·70	25·52	17·03	1·1244	34·7	212	198
Liverpool . . .	633,645	1,498	23·98	26·33	17·44	1·0980	35·2	184	189
Mean of 33 Towns . .	11,218,378	1,171	19·03	20·58	17·71	1·0813 *0·9845	30·3	178	167

* England and Wales, less 33 towns.

The Normal Constitution of the Population of England and Wales in 1881 *was*—

	All ages.	0—5	5—10	10—15	15—20	20—25	25—35	35—45	45—55	55—65	65—75	75, &c.
Both Sexes.	1,000	136	121	108	98	98	146	113	84	59	33	13
Males.	486	69	60	54	49	43	71	54	40	28	15	6
Females.	514	67	61	54	49	46	75	59	44	31	18	7

Normal Death Rate at each Age

Mean annual death-rate of each age per 1000 living.	Males.	68·14	6·67	3·69	5·23	7·32	9·30	13·74	20·5	34·76	69·57	169·08
	Females.	58·10	6·20	3·70	5·43	6·78	8·58	11·58	15·59	28·54	60·82	155·83
	Ages.	0—5	5—10	10—15	15—20	20—25	25—35	35—45	45—55	55—65	65—75	75, &c.

Population estimated or enumerated and recorded, Birth and Death-rates for recent years of certain Scottish, Irish, Continental, Colonial, and American cities.

	Population.	Birth-rate.	Death-rate.		Population.	Birth-rate.	Death-rate.
Edinburgh	295,628	27·5	19·7	Lyons	438,077	19·2	20·4
Glasgow	724,349	33·6	21·2	Lille	200,325	31·8	23·5
Dublin	349,594	31·2	26·8	Brussels	551,011	24·5	16·8
Belfast	304,610	36·9	25·5	Rome	499,861	22·4	17·9
Berlin	1,773,003	26·7	17·3	Turin	344,203	20·9	19·6
Hamburg	661,015	32·1	17·9	Florence	199,080	23·6	21·9
Dresden	397,300	33·1	19·1	Venice	169,545	23·2	22·6
Frankfurt-a-M.	229,279	30·1	16·5	Trieste	165,177	31·3	28·2
				Vienna	1,590,295	30·2	20·1
Breslau	392,795	35·4	24·8	Prague	382,029	28·0	23·8
Munich	430,000	36·4	25·1	Buda Pesth	648,104	35·4	22·1
Amsterdam	503,319	29·6	17·1	St. Petersburg	1,132,677	28·5	25·8
Rotterdam	303,878	36·2	18·6	Sydney	432,625	28·3	12·7
Copenhagen	345,000	29·7	17·9	Melbourne	475,380	26·2	15·4
Stockholm	283,550	26·2	17·3	Toronto	181,220	22·5	15·8
Christiania	221,255	33·6	16·8	Montreal	216,650	34·4	33·7
Paris	2,511,629	23·6	19·7	Quebec	63,090	34·8	24·4
New York	3,550,058	?	18·4	Philadelphia	1,266,832	?	18·8
Boston	547,263	29·3	20·1	St. Louis	623,000	19·1	14·3
Cincinnati	405,000	16·3	14.8	San Francisco	360,000	14·2	19·4

The age and sex constitution of such populations as San Francisco and other rapidly growing towns are, however, so abnormal as to render comparisons useless.

The general relation of the "health and wealth" of a people on the birth and death rates, and the age constitution of the population may be thus summarised :—

The health of a people lowers the death rate, and prosperity raises the birth rate, unless voluntary and artificial checks are imposed.

Increased length of life implies decrease of death rate, and *vice versâ*, but not necessarily increase of population, which depends on excess of births over deaths. With a decreased death rate there will be a larger proportion of

adults if the decreased death rate be mainly among children, or of the aged if among adults.

The death rate is dependent on the sanitary conditions of a community, and is thus under legislative control.

The birth rate depends greatly on the age at marriage and on the fertility of females, *i.e.,* on the action of individuals rather than on that of the state.

It is strikingly connected with the demand for labour, with emigration, and with any need for men to fill the vacancies caused by death. Thus, after wars and pestilences, a population increases rapidly, young men filling the places of the deceased and at once marrying thereon. Rising industries, mines, or manufactories, in like manner lead to numerous marriages and propagation. The birth rate depends on the constitution of the population, chiefly as affected by employments; the death rate, on the constitution of the population as regards ages and sanitary conditions.

The influence of manufactures and emigration is shown by a comparison of England and France.

With their proverbial thrift, the French carry out the principles enunciated by Malthus, imposing artificial checks on the production of children and the increase of the population beyond the food-producing powers of their native soil, and are less given to emigration than any people in Europe. In England, and still more in Germany, the natural increase is high, food being imported in exchange for its equivalent in manufactures, and a constant stream of young adults going forth to people other quarters of the globe.

The constitution of the population in France is therefore very different from that of England, Germany, or Italy, and renders all comparisons of the crude death rates fallacious, giving also a larger proportion of old people, and consequently a higher mean age at death and *apparently* greater longevity.

The expressions "high" and "low" death rates, and "excess of births over deaths," though convenient, are strictly inaccurate, and, unless understood in a qualified

and technical sense, are apt to mislead. Since these events must once and once only occur to every individual, their numbers must in the end be the same, or 100 per cent. of the entire population. Differences in the death rate, so-called, are in reality due to differences in the relative proportions of deaths occurring prematurely, and in that sense only must one be understood when speaking of so many lives saved annually, as when we say that a man has been saved from death by drowning, though only to die at some future time. Death is the natural termination of life, and inevitable; but all disease is unnatural, and is, or ought to be, preventible, as then would all deaths be other than those from old age. The aim of the sanitary reformer is to abolish disease and to prolong life to its utmost limit, and the effect of a so-called reduction of the death rate is only to delay the inevitable event. An apparent excess of births over deaths, again, is due to a constant increase in geometrical progression of the relative proportion of actively reproductive individuals in a community, and should the number of births decline, from a general disinclination to marriage, on prudential or economic grounds, an improvement in the public health, manifested in a present reduction in the death rate, would towards the close of the existing generation lead to a corresponding rise, though the mean age of the dying would be higher. This is a contingency deserving of serious consideration in view of the tendency at the present time to a falling off in the marriage and birth rates in this country. In all circumstances it is evidence of a better state of the public health when the mean age at death rises, while the mortality of infancy and childhood, as well as that due to infectious diseases and insanitary conditions, shows a continuous decline.

Death Rates

I have insisted on the worthlessness of crude death rates, and the necessity for their correction on the basis of the constitution of the population, since, *e.g.*, all other conditions being the same, and the mortality at each age period identical in two communities, the fact of one having half again as many children as the other might make a difference of 4·5 per 1,000 in the death rate.

Death rates are calculated as per 1,000 living, whether at all ages or within the particular age period, thus : If in a town having a population of 120,000, there were 2,400 deaths in the year,

$$\frac{2,400 \times 1,000}{120,000} = 20 = \text{the death rate per 1,000 population.}$$

From this we can obtain the converse statement, $\frac{1,000}{20} = 40$, that one person in forty dies in the year.

The deaths of infants, children, and persons over sixty or sixty-five should always be calculated on the number of those living at the same ages. The statements so constantly met with, that the deaths of infants and of old persons were so many per 1,000 of the population, or of the deaths at all ages, are utterly useless, and for purposes of comparison misleading, since the relative proportions of such persons to the rest of the population may differ greatly in different places.

It is, of course, at the census only that this can be known with certainty, and for the intervening years recourse must be had to estimates ; but the infant population cannot differ appreciably from the mean of the births of the current year and of that immediately preceding, though for all practical purposes it is enough to calculate the deaths on the births of the same year.

The child mortality or the deaths of children under five years is a matter of no less significance, since it is in early

childhood that infectious diseases and the effects of neglect and exposure, as bronchitis, &c., are most fatal. The child population may be "estimated" in the usual way, but I think with greater approximation to the truth by a method which I proposed in 1884, in the first edition of this work.

"Add together the total births of the five previous years, and deduct from the sum the number of deaths under one year of age in the first of these years, under two in the second, and so on. The remainder will be the number now living under five." Errors arising from immigration and emigration may generally be left to correct one another.

Infant Mortality from All Causes per 1000 *Births.*

	1871—80.	1881—90.
England	148	—
London	156	151·5
Liverpool	199	182·7
Manchester	178	178·9
Salford	182	186·5
Leicester	200	197·9
Birmingham	172	173·5
Portsmouth	141	138·5

In those countries from which we have trustworthy statistics the extremes are 85 to 105 in the Faroe Islands Ireland and Norway, and over 300 in Bavaria and Iceland. Italy holds a middle place as regards infancy, but by the fifth year the mortality has overtaken that of Bavaria.

The question of infant mortality is closely connected with that of infant feeding, and these extraordinary differences are mainly, if not wholly, explicable in this way. In the Faroe Islands and in Norway infants are invariably breast fed, while in Iceland and among the working classes in Bavaria they are as constantly brought up on sopped bread and farinaceous foods. It is a fact full of instruction that when during the sufferings and starvation caused by the siege of Paris the general mortality of the population was doubled, that of the infants was reduced by 40 per cent., simply from the mothers being compelled by circumstances

to suckle their babies; and the same increase in the adult and reduction of the infant mortality was observed during the Lancashire cotton famine, when the mothers were no longer at work in the mills.

Where improper feeding is the chief factor, a large proportion of the deaths are due to diarrhœa and other disorders of the stomach and bowels, convulsions, &c., and relatively fewer to other causes of a less preventible kind.

In northern and western Germany the infant mortality is no higher than in England, and that in France appears to be as low, but the French figures are deceptive, since infants dying before registration are reckoned as stillborn!

The late Dr. Letheby propounded a doctrine as fallacious as that of Malthus and more dangerous, viz., that a high birth rate involved a high death rate, the latter acting as a natural check on the increase of population.

It is true that if the high birth rate be the result of general illegitimacy, of improvident marriages, &c., the consequences will be a proportionally high death rate, and a teeming but short-lived population. But if the high birth rate be the natural and direct result of prosperity and of high wages, as in industries where only adult males are employed, or in flourishing colonies, the birth rate will greatly exceed the death rate, the sanitary conditions being good.

Of course infancy is more tender than manhood, and where there is a large infant population there will necessarily be more deaths than where children are few. But, if more than half of the children survive, a high birth rate must after some years lower the general death rate; since if long maintained it leads to an accumulation of young adults at a period of life when the death rate is lowest, and to a lessened proportion of aged persons, who, after infants, furnish the largest contingent of deaths, thus more than compensating for the necessarily higher proportion of deaths in infancy and childhood.

PREVENTIBLE DISEASES

All disease is unnatural, and is, or ought to be, preventible; but the term is conventionally applied to those diseases which, arising directly or indirectly from insanitary conditions, or being propagated by infection, are more under the control of the State and society, and

amenable to sanitary regulations, than those depending on heredity, or personal constitution, or habits.

It is to the reduction of this mortality, if not to the extinction of the diseases themselves, that the efforts of the sanitary reformer are directed ; the others must be left to the physician and the educators of the people. That it is not utopian to aim at the total abolition of any given preventible disease is seen in the enormous and rapid reduction in the mortality from typhus, which it seems will ere long be as little known in this country as the plague, and in the virtual disappearance of small-pox from the whole of the German Empire, where the few occasional cases of late years have been invariably the direct results of importation from Russia, Italy, Austria, or France.

It has been said that the reduction of one cause of death leads to an increase of others. In one sense this is true, since every one must die at some time from some cause or other, and the success of sanitary measures is seen in the reduction of the deaths from preventible causes. But the fallacy consists in ignoring the influence of mean age on the prevalent diseases. Thus, of 1000 persons dying from all causes in 1861 to 1871, there died of

	Scarlatina.	Consumption.	Cancer.
In the healthy districts . .	21·4	108·5	27·5
In Liverpool	38·3	96·6	9·9

These are diseases respectively of early, middle, and advanced life. It is not that there was less phthisis or cancer in Liverpool, but so many persons died in youth that fewer attained the age at which they became liable to those diseases. Thus, an increase in the deaths from diseases incident to advanced life may really indicate a general prolongation of life from improvement in the public health.

The following table affords the clearest evidence of the success that has followed the legislation and expenditure on sanitary improvements within the present generation.

Mean Annual Death Rate per 1000 *Living from Certain Diseases and from All Causes in Successive Quinquennia from* 1860 *to* 1890, *etc., in England and Wales.*

	1861—65.	1866—70.	1871—75.	1876—80.	1881—85.	1886—90.
Smallpox	·2188	·1048	·4114	·0784	·0784	·0132
Measles	·4570	·4288	·3734	·3854	·4130	·4684
Scarlatina	·9832	·9602	·7590	·6804	·4358	·2406
Typhus			·0816	·0334	·0228	·0066
Enteric	·9224	·8504	·3740	·2774	·2160	·1792
Continued			·1402	·0692	·0342	·0166
Whooping cough	·5160	·5452	·4990	·5276	·4386	·4436
Diphtheria	·2470	·1268	·1208	·1218	·1562	·1696
Diarrhœa and Cholera	·9170	1·2360 (Cholera in 1866)	1·0316	·8540	·6720	·6810
Phthisis	2·5280	2·4492	2·2192	2·0424	1·8304	1·6354
Childbirth	·1134	·1060	·1076	·0796	·0728	·0660
All causes	22·5950	22·4365	21·9752	20·8170	19·4034	18·8954

These results are really due to sanitary improvement consequent on legislation, for no such difference is to be observed between the decades 1850-60 and 1860-70. Small-pox is subject to waves of epidemic, but all the others (though epidemic years are followed by years of remission, until a susceptible generation has taken the place of the past) have steadily declined, except whooping cough, which is independent of, and not amenable to, any sanitary measures; and measles, which has increased greatly in London and the large towns since the passing of the Education Act, and the consequent massing of children in elementary schools. Diphtheria, too, has shown a tendency to increase of late, partly from the same cause, but also perhaps, in appearance only, from the correct diagnosis of cases which would in former years have been reported under other names.

The lowest present mortality, or as it may be called the "permissible mortality," from the chief preventible diseases may be roughly stated as

Diphtheria . . . 0·1	Scarlatina . . . . 0·4	Measles (London) . . 0·6
Enteric fever . . 0·2	Whooping cough . 0·5	Phthisis . . . . . . 1·5
Measles . . . . 0·3	Diarrhœa . . . . 0·6	

These figures arranged in a regular progression may be easily remembered, and anything above them should arouse to action. Diphtheria and enteric fever are most suggestive of insanitary external conditions, diarrhœa and phthisis also, though perhaps depending on personal conditions. Measles, scarlatina, and whooping cough, and diphtheria to some extent are determined

also by social conditions, *i.e.*, they are spread by personal intercourse in schools, &c.

Tuberculosis is a communicable disease propagated by the inhalation of the spores floating in the dust from dried sputa, and therefore most prevalent among persons working in crowded and ill-ventilated rooms (whence it was formerly ascribed to the mere fact of breathing an atmosphere charged with the products of respiration), or in the case of infants, in whom the intestinal glands are mostly attacked, to the ingestion of the milk of tuberculous animals.

Phthisis is induced by repeated catarrhs and favoured by dampness of sites, defective drainage, &c., and also by the irritation consequent on the inhalation of dust of any kind.

Enteric fever is most fatal in early adult life, but diphtheria and scarlatina most, and whooping cough and measles exclusively, in childhood. The mortality from diarrhœa, the dominant factor in the death rate of the third quarter of the year, falls also heaviest on infancy and childhood.

The so-called "zymotic death rate" is useless as an indication of the health or sanitary condition of a community; the several diseases should always be specified, for a high mortality due to an outbreak of measles or scarlatina in schools, though calling for preventive measures, may be of far less enduring import than a much lower death rate from enteric or diphtheria.

Combined Death Rates.—In calculating the general death rate of two or more communities or classes of persons locally or otherwise associated—as the population of adjoining districts, the members of two similar or diverse professions, or the troops stationed at home and abroad—it is not enough to take the mean of the several rates, unless the number of persons in each is the same.

Thus, if in a manufacturing town of 80,000 inhabitants there were 2,400 deaths per annum, and in an adjoining residential suburb 20,000 with 320 deaths, the respective rates would be 30 and 16 per 1,000, but the mean 27·2 not $\frac{30+16}{2} = 23$. We must add the populations and the deaths, and then determine the rate

$$80{,}000 + 20{,}000 = 100{,}000, \text{ and } 2400 + 320 = 2720$$

$$\therefore \frac{2720 \times 1000}{100{,}000} = 27{\cdot}2.$$

Local Death Rates.—The example just given of combined death rates will serve to expose the dangerous fallacy of conclusions as to the health of large towns drawn from the mean death rate of the population taken as a whole.

For if in a like population of 100,000 there were wards comprising 60,000, or more than half with a death rate of 20, a wealthy suburb containing 20,000 inhabitants having a still lower death rate of 16, and a poor and densely-peopled quarter with 20,000 inhabitants and a death rate of 32, the mean for the entire population, viz., 21.6, would appear very satisfactory, and might be urged by so called "economists" as an argument against any considerable expenditure on the sanitary improvement of the poorer quarters of a town whose death rate compared very favourably with those of any of like size. The boast of Londoners that their city is one of the healthiest in the world is based on the general death rate of about 20, but this, by throwing together Hampstead and Holborn, Kensington and Bermondsey, conceals the fact that in districts as populous as many a provincial manufacturing town the rates are as high as 34 and 38 per 1,000!

Great as are the gains in economy and efficiency of administration from the unification of local government, for which Manchester and Salford, Liverpool and Birkenhead, Brighton and Hove, might with advantage be constituted single boroughs, the vital statistics, especially the "corrected" death rates, of divisions distinguished by the general characters of the houses and populations should always be recorded and published separately.

Class Death Rates.—The death rates of particular classes or sections of the population should be compared, if comparisons be possible, with those of persons of the same sex and age periods, not with that of the general

population. For example, in a town where the general death rate was 20, one of 10 among factory girls between the ages of 15 and 30 would be very high, since that of young women during this period is not more than 6. This is even more necessary when either the regulations of the service or the exigencies of the employment involve a selection of lives and exclude all but the healthy and robust.

Special Death Rates.—There are classes, of which the army may be taken as the type, which I would propose to call, provisionally at least, "perpetual populations." Not only are they composed exclusively of men originally selected by a strict medical examination, and within the least mortal period of life, but every one who is subsequently found to be in failing health is removed and his place taken by another more robust. To compare their death rate with that of males generally, of those of like ages, or even of the selected lives of Insurance Societies, in which no such weeding process goes on, is a fraud. Indeed it may be said that no soldier ever dies in the service save by accident or mistake, *i.e.*, by violence, acute illness, or the neglect of the medical officers to invalid him in time. The so-called death rates of the army, whether from all causes or from particular diseases, as phthisis, are intangible, illusive, and arbitrary, depending more on official vigilance than on the sanitary conditions of life in the barrack.

The only legitimate comparison that may be made as to the health of the army is with itself at different periods, and that only provided the losses by death *and invaliding* are thrown together, and the sum calculated per 1000 living at each age, and under like conditions for at least several years consecutively, which can rarely if ever be predicated, except of the Guards. To compare the losses from any or all causes of two regiments, one returned from a tour in Lower Bengal and the other from Upper Canada, would, however just as evidence of the influence of foreign service in different climates on the health of the soldier,

be manifestly unfair as an indication of the sanitary conditions of the barracks, or home stations, where they chanced to be located on their return.

Hospitals constitute another special class prolific in fallacies. The mortality must, of course, be calculated on the number of persons passing through them in the course of the year, not on the number of beds, since in a hospital having 100 beds where the average period of treatment was six weeks, 100 deaths per annum would represent a mortality not of 100 per cent., but of 100 in 800, *i.e.*, of 12·5 per cent.

It is seldom that any plausible, not to say impartial, comparison can be drawn between different hospitals, since the mortality is determined by the nature of the cases admitted and retained, rather than by the treatment, or even the sanitary surroundings. If septicæmia haunt the surgical wards, or diphtheria and enteric originate within the building, there is evidently a local cause; but to contrast the general mortality of large hospitals in populous seaport and manufacturing towns, where severe surgical cases are daily admitted, and in the medical wards of which only the gravest can be received, with the small infirmaries in some health resort, or quiet cathedral city, where the accidents are comparatively slight, and patients are retained as in a convalescent home, is unjust to the former if on the basis of admissions, and dishonest if on the number of beds. Yet the advocates of small hospitals constantly compare the results of operations and the general mortality in hospitals of a hundred or even fifty beds in provincial towns, with those in hospitals having 500 or 600 in London, Manchester and Glasgow; ignoring the fact that the difference in size is itself evidence of the difference in the conditions, which to justify conclusions from the results ought to be the same in all respects except the one at issue. Provided the class of cases and the pressure on the resources of the hospitals be the same, it would be perfectly legitimate to compare the mortality in one of the old insanitary solid buildings with that in a new one in the immediate vicinity having a like number of beds, but distributed in eight or ten blocks or pavilions with fifty to sixty in each.

Comparative Mortality of Various Professions and Trades.

Although individuals may be found enjoying good health and attaining to great ages under the most unfavourable conditions, and amid insanitary surroundings, the general tendency of the unnatural character of civilised life as seen in large cities, and of the physical and mental pressure of the struggle for existence is to shorten life whether by disease or by premature decay.

But the common practice of quoting the mean age at death as an index of the healthiness or otherwise of any occupation is fraught with fallacies. The longevity of judges, bishops, and generals is well known, and that of pensioners is proverbial, but the explanation is not so much the character of their professions as that the heads are selected from among those members who, having already attained a good age, are in full possession of their physical and mental powers, and have therefore a higher expectation of life than their younger brethren, many of whom are breaking in health at ages far short of that at which these are appointed ; and pensioners are men who after long and efficient service enjoy repose and freedom from anxiety or hardship.

There are positions to which men rise after having passed through others as a preparation, or for which the qualifications are not so much strength and activity as tried honesty, steadiness, and trust ; on the other hand many for which only men in the fullest vigour of early manhood are eligible, and again many in which the youth of both sexes are employed, who before long seek more lucrative or less laborious occupation. Then the influence of the marriage market on female labour is such as to falsify all conclusions from these data.

To say as Dr. Rohé does that judges live longer than lawyers, pilots and light-house keepers than seamen, bankers and merchants than their clerks, and professors than students ! is merely to state the truism that old men live longer than those who die young. The mean age at death of his "soldiers" is twenty-eight, but soldiers cease to be such after thirty, mostly indeed before that age. His "gentlemen" are far older at death than tradesmen, &c., for had they died earlier they would have been returned under some trade or profession.

In the case of females, the mean age at death is still more deceptive, since very few, except perhaps monthly nurses, follow their employment throughout their lives. I believe that, however unhealthy sedentary work in close rooms may be, the early age at death, and consequently the apparently pitiable condition of dressmakers, milliners, &c., is largely explained by the marrying off of all those who are likely to live long. Certainly few domestic servants die as such, and the great majority are removed by marriage and not by death.

Let us imagine a few hundred strong good-looking girls, engaged between the ages of seventeen and thirty in a healthy and agreeable employment, and that excepting a few who die from one cause or another, they all get married or turn to some more responsible or lucrative occupation before they reach the age of thirty. To give twenty-five as the mean age at death of girls thus employed, on the strength of a few exceptional cases, would be absurd. Suppose again, what is by no means improbable, that in the next ten years none should die, it would be less credible indeed, but not more illogical, to say that girls while so employed never died at all !

Domestic servants rarely if ever die at the houses where they were employed ; they return to their homes when seriously ill, and if they live some months longer are very likely described in the death certificate as of "no occupation." Their homes too are mostly in other

registration districts, very often in the country, and their places are taken by fresh recruits.

The effect then of a large number of female servants in a town is to lower the death rate to the same extent as would a like proportion of immortals permanently resident among a mortal population, while those who die at home raise the death rate of places where they were not reckoned among the living.

Another prevalent fallacy in estimates of the mortality of trades, &c., is that of ascribing an undoubted high mortality to *one particular cause, perhaps a real and powerful factor, but yet only one among others not less powerful.* Thus "temperance advocates" are constantly appealing to the acknowledged high mortality in the strictest sense of the word among tavern keepers and their assistants, as if it were wholly due to habits of indulgence in alcohol. Probably, in the case at any rate of the masters, much may be due to drink, but it is doing them, and still more their assistants, an injustice to ignore their unhealthy surroundings. If long hours and deficient ventilation tell on the health of drapers' assistants, tailors, sempstresses and printers, how much more must the far longer hours, the fouler air, amid blazing gas-lights and the exhalations of a crowd of the "unwashed" act injuriously on the health of the young men and girls who have to stand behind the bar from early morning till past midnight without even a weekly day of rest!

Tables of Comparative Mortality.

Dr. Ogle has shown that the only legitimate comparison between the mortalities of the several trades and professions, is the relative numbers dying between the ages of twenty-five and sixty-five out of an equal number of each living at those ages.

Finding that among 64,641 males living between those ages 1,000 die every year, and taking this as a standard or unity, he gives the number that would die annually of a like number of males in any given occupation as the "comparative" mortality in each case; and also employs as a further measure of the health of each the mean annual death rate per 1,000 living between the ages of 25–45 and 45–65.

These ages are chosen because before twenty-five years many have not fully entered on the duties of their several occupations, while those that have cannot be expected to have been materially affected thereby; and after sixty-five the well-to-do have for the most part retired from active labour, and the poor are supported by their friends or by the State, while as a rule the mid-period marks a change in the conditions. In the more or less unhealthy trades the unfavourable influences begin to manifest their effects, while in others, especially the professions, the work becomes less arduous, and the mortality due to the employment, over and above that incident to advancing age becomes greater or less than in the preceding period respectively.

It would, however, have been better to have taken "occupied," rather than all males, as the standard, since even among the so-called "leisured" classes there are few absolute idlers. The life of the country gentleman is as much one of active employment as that of his steward or gamekeeper, and the really "unoccupied" are so for the most part in consequence of some defect or infirmity bodily, mental, or moral, which cannot but be more or less unfavourable to longevity. The change of standard would, however, make no material difference, as the relative position of only two or three groups would be altered thereby.

The groups are well defined and comprehensive, excessive sub-division being avoided, and those masters who live under conditions having nothing in common with those of their men are not included in the several trades.

Dr. Ogle's Table of Comparative Mortality of Professions and Trades.

Occupation.	Mean Annual Death Rate per 1000 living. 1860—1871. Years of Age. 25—45	1860—1871. 45—65	1880-1-2. Years of Age. 25—45	1880-1-2. 45—65	Comparative Mortality Figure. 1880-1-2. Years of Age. 25—65
All males	11·27	23·98	10·16	25·27	1000
Occupied males	—	—	9·71	24·63	967
Clergy, Priests, Ministers	5·96	17·31	4·64	15·93	556
Gardeners and Nurserymen	6·74	17·54	5·52	16·19	599
Farmers and Graziers	7·66	17·32	6·09	16·53	631
Agricultural Labourers	—	—	7·13	17·68	701
Schoolmasters and Teachers	9·82	23·56	6·41	19·98	719
Grocers	9·49	17·15	8·00	19·16	771
Fishermen	11·26	15·84	8·32	19 74	797
Carpenters and Joiners	9·44	21·36	7·77	21·74	820
Booksellers, Stationers	10·84	21·36	8·53	20·57	825
Barristers, Solicitors	9·87	22·97	7·54	23·13	842
Drapers and Warehousemen	14·34	26·33	9·70	20·96	883
Grooms and private Coachmen	—	—	8·53	23·28	887
Coal miners, mean of six districts	—	—	7·64	25·11	891
Plasterers and Whitewashers	9·50	27·9	7·79	25·07	896
Watch and Clockmakers	10·78	24·90	9·26	22·64	903
Tanners, Fellmongers	10·43	26·57	7·97	25·37	911
Shoemakers	10·39	22·30	9·31	23·36	921
Artists, Sculptors, Engravers, Architects	11·73	22·91	8·39	25·07	921
Commercial Travellers	12·28	29·00	9·04	25·03	928
Corn Millers	9·32	26·65	8·40	26·62	957
Bakers, Confectioners	10·72	26·39	8·70	26·12	958
Builders, Bricklayers, Masons	11·43	27·16	9·25	25·59	969
Blacksmiths	10·07	23·88	9·29	25·67	973
Commercial Travellers, Insurance Agents	14·28	28·88	10·48	24·49	996
Tobacconists	13·19	21·76	11·14	23·46	1000
Chemists and Druggists	13·92	23·56	10·58	25·16	1015
Tailors	12·92	24·79	10·73	26·47	1051
Printers	13·02	29·38	11·12	26·60	1071

Dr. Ogle's Table of Comparative Mortality of Professions and Trades.

Occupation.	Mean Annual Death Rate per 1000 living.				Comparative Mortality Figure.
	1860—1871. Years of Age.		1880-1-2. Years of Age.		1880-1-2. Years of Age.
	25—45	45—65	25—45	45—65	25—65
All males	11·27	23·98	10·16	25·27	1000
Occupied males	—	—	9·71	24·63	967
Wool and Worsted Manufacturer Operatives, West Riding	—	—	9·71	27·50	1082
Cotton and Linen ditto, Lancashire	—	—	9·99	29·44	1088
Medical Men	13·81	24·55	11·57	28·03	1122
Law Clerks	18·75	37·05	10·77	30·79	1151
Butchers	13·19	28·37	12·16	29·08	1170
Glass Blowers, &c.	13·19	29·32	11·21	31·71	1190
Plumbers, Painters, and Glaziers	12·48	34·66	11·07	32·49	1202
Cutlers, Scissor, Saw, Tool and Needle Manufacturers	11·88	32·74	11·71	34·42	1273
Carters, Carriers, and Hauliers	—	—	12·52	33·00	1275
Bargemen, Lightermen and Watermen	14·99	30·78	14·25	31·13	1305
Musicians and Music-masters	18·94	34·76	13·78	32·39	1314
Hairdressers	15·11	30·10	13·64	33·25	1327
Brewerymen	19·26	36·86	13·90	34·25	1361
Cabmen, Omnibusmen	15·94	35·28	15·39	36·83	1482
Chimneysweeps	17·53	42·87	13·73	41·54	1519
Innkeepers, Licensed Victuallers	18·01	34·14	18·02	33·68	1521
Messengers, Porters, Watchmen	—	—	17·07	37·37	1565
Filemakers	16·27	42·30	15·29	45·14	1667
Earthenware Manufacturers and Potters	12·59	41·75	13·70	51·39	1742
Cornish Miners	11·94	41·73	14·77	53·69	1839
Costermongers, Hawkers, &c.	20·09	37·82	20·26	45·33	1879
General Labourers (London)	18·35	40·64	20·62	50·85	2020
Inn and Hotel Servants	21·91	42·19	22·63	55·30	2205

At least one-fifth of the deaths among miners are due to accidents, and this is the case also with quarrymen. Except in Cornwall they are remarkably free from phthisis, though in South Wales the phthisis mortality appears somewhat higher than among the general population.

Influence of Ventilation in Production of Phthisis and Respiratory Diseases.

The influence of defective ventilation in the production of phthisis is seen in the following table :—

	Phthisis.	Diseases of Respiratory system.	The two together.
Fishermen	108	90	198
Agriculturists . . .	115	122	237
Grocers	167	116	283
Drapers	301	129	430
Tailors	285	186	471
Printers	461	166	627

The influence of the inhalation of dust, with or without defective ventilation, in the production of phthisis and other respiratory diseases is seen in the following table :—

	Comparative Mortality Figure.	Phthisis.	Other Diseases of Respiratory Organs.	The two together.
Coal-miners	891	126	202	328
Carpenters	820	204	133	337
Bakers, &c.	958	212	186	398
Masons, Bricklayers	969	252	201	453
Wool manufacturers .	1032	257	205	462
Cotton manufacturers	1088	272	271	543
Quarrymen	1122	308	274	582
Cutlers, &c.	1309	371	389	760
File Makers	1667	433	350	783
Earthenware mnfrs. .	1742	473	645	1117
Cornish miners . . .	1839	690	458	1148
Fishermen	797	108	90	198

Birth Rates

The birth rate in this country from 1840 to 1890, *i.e.*, practically from the commencement of the system of registration to the present time, a period of fifty years, has been at the mean rate of 33·8 per 1000 of the total population, the maximum of 36·5 having been reached in 1876, and the curve beginning and ending with the minimum of 30 to 31. But in comparing one community with another, whether in the same country or not, age and sex must be taken into account. Either a standard constitution being assumed the necessary factor based on the fertility of women at different ages must be determined, or the rate must be calculated on the number of probable or possible mothers, *i.e.*, on the married or the marriageable women of reproductive age, who may respectively be considered as the active and reserve forces employed in or available for the maintenance and extension of the community.

The extremes of fifteen and fifty years, or those of twenty and forty-five, which include the overwhelming majority of mothers, suggest themselves, and it is not easy to determine which is the better for national or international purposes; probably the former is the safer, since in some countries a large proportion are mothers under twenty, and everywhere such girls, if married, would in most cases be productive; while the procreative period being limited to about thirty years, the numbers of actively child-bearing women in each of the terminal quinquennia would about balance one another.

Illegitimate births should be calculated either on the legitimate or on the unmarried female population of procreative age. But it would be well in this case to divide this period into two of 15–30 and 30–45 years; the victims of seduction, kept women and those of loose morals being for the most part young, and many of them being afterwards married. In England the mean illegitimate birth rate has, since the commencement of registration, steadily fallen from 2·25 to 1·4 per 1000 population, but

the rate, especially when corrected by relative proportions of unmarried women, will be found to vary greatly in different districts in a way by no means easy to explain, London and the counties south of the Thames having the lowest amount of illegitimacy ; Norfolk and Cumberland, with little in common, unless possibly in the housing of the agricultural labourers, giving the highest percentage ; while the mining districts and in a less degree the manufacturing towns are above the mean, probably from the respective degrees of uncontrolled association of young men and girls.

The high rate of mortality among illegitimate children is notorious, but it is wholly due to the neglect consequent on the shame attaching to their birth, and the more "moral" the tone of society the greater this "slaughter of the innocents." Thus in some of the Argentine states, where half the population is born out of wedlock, no such difference in the death rate is observed ; since public opinion does not demand that these fatherless infants shall be handed over to the "baby farmer," or as the French express it, the *faiseur des anges!*

Whether early marriages are more prolific than late ones is doubtful ; that is to say within reasonable limits : probably women marrying between twenty and twenty-five years have at least as many children as those who do so at earlier and often immature ages, but the effect of a preponderance of early marriages is a rapid increase of the population, if only by shortening the interval between each generation ; whether these be as in Ireland and among the lower classes in towns, the result of reckless improvidence, or on the other hand the natural consequence of an ample supply of the means of subsistence. The influence for good and for evil on the moral and social conditions of a population of a large proportion of early marriages especially of men, is a complex but serious question.

It must however be remembered that a skilled artisan, unlike a professional or commercial man, is in a position to earn a

full income at an age little above twenty and that his power of earning does not increase with his age, but rather the reverse. While a man in the middle classes is as a rule in a far better position to bear the expenses of educating a family after the age of forty than he was ten years earlier, it is to the interest of the working man to have his children off his hands before his wage-earning powers begin to decline, or he die leaving them a burden to his poor widow or chargeable to the parish.

The mean age at marriage in England is at present for men twenty-six, and for women twenty-four, but 7 per cent. of the former and 21 per cent. of the latter marry under twenty-one years. In reality the proportion is greater, at any rate among the poor of London, boys and girls making false statements, often with the connivance of their parents. The number of children to each marriage is in this country four and a half on an average, but a more accurate estimate of the fecundity of women in any community or class would be furnished by the number of children to each married woman: for the remarriage of a widow does not mean the foundation of a new family, it simply prolongs her activity which had been temporarily arrested, as if her first husband had survived, since it is only in cases of extreme disparity of age that a woman's procreative power outlasts that of her husband: in short the question is how many children a woman bears, not how many husbands she happens to wed?

More men than women marry, for the remarriages of widowers are more than half again as frequent as those of widows, and widowers more often marry spinsters than widows marry bachelors.

The marriage rate varies directly as the fluctuations of trade. In times of commercial activity and speculation, often erroneously called "prosperity," numbers of men finding employment enter into the marriage state, but this period of "eating and drinking, marrying and giving in marriage," as Dr. Farr described it, is in due time followed by a collapse and a longer or shorter depression, during which the marriage rate falls to its former figure.

The birth rate follows the marriage rate pretty closely, but the connection is not so obvious as it would at first sight appear to be, for women continue to have children for ten or twenty years. The explanation is probably to be found in the fact that while of married women in general only one in three or four gives birth to a child every year, at least half do so in the first year after marriage.

Malthus taught that while population increased in geometrical progression, the food producing power of a country could not increase but in arithmetic progression,

and that when the land was wholly brought under cultivation, &c., it was incapable of further increase. This would be true of an island, cut off from all intercourse with the rest of the world, the inhabitants of which were wholly dependent for subsistence on the fruits of their soil and their herds. But this argument takes no cognisance of the system of barter and exchange on which the whole fabric of civilisation rests. The means of subsistence include food *and its equivalents*. So long as there are lands capable of producing food in excess of the needs of their inhabitants, who are willing to exchange such surplus for things which their land does not produce or which they cannot themselves manufacture, this surplus food is at the service of any other people possessed of mineral wealth or able to import raw materials, and, having manufactured them, to return them at an enhanced value, exchanging the difference for food.

The only limit to the power of such a people to produce, not food, but the means of obtaining food, is that of the world's demands for that which they can give in exchange for food, to which a maritime people may add the remuneration of their services in the carrying trade for others. Indeed the wealth of the Venetians and Dutch, the former before and the latter after the discovery of the sea route to India, was wholly due to their monopoly of this carrying trade, which we now enjoy not as exclusively as they did, but in a larger degree than any other nation. Any country in time of peace, and one that can maintain the command of the sea in time of war, may thus stand to the whole world in the same relation that London, Manchester, Birmingham, and Liverpool do to the rest of the United Kingdom.

Under such circumstances an increasing population so far from reducing the means of subsistence, actually increases *pari passu* the potential wealth of the nation, *i.e.*, its means of procuring the food it cannot produce at home. At the same time the emigration of the redundant population to new and previously undeveloped countries, founding there young and rising communities with all the wants of civilisation, which for a long time they are themselves unable to supply, creates extensive markets for the home trade. It is thus that Great Britain has been able to call into existence the nations of North America, the Cape,

and Australia, which, without taking into account the natives, and even the accessions from other European nations, already outnumber the population of the mother country; whereas France, which has adopted the principles of Malthus, and where the production of children is deliberately restricted to the possible provision for them at home and for the most part on the soil, remains without colonies and is both numerically and politically stationary if not retrogressing, the small increase in her population during the past twenty years being almost wholly due to the immigration of Germans, Belgians, and Italians. It is remarkable, as showing the voluntary nature of the infertility of marriages in France that the French Canadians, one of the most prolific as well as thrifty people on the face of the earth, are descendants of emigrants from Normandy, the province in which more than in any other the births fall short of the deaths. Yet notwithstanding the extremely early age at which both sexes marry and their enormous fertility the French Canadians are physically immensely superior to their European cousins.

But under no circumstances is there any need for imposing artificial restrictions on the natural increase of a people, since the equilibrium between a population and its means of obtaining subsistence is maintained unconsciously by the law which regulates supply and demand for men no less than for the products of industry, shown by the interdependence of employment and marriage. To recognise the extent to which this operates it is only necessary to remember that the number of single women between the ages of twenty and thirty-five is half again as great as that of the married; and even if we deduct a third of these as for one cause or another ineligible, it is easy to see that if it were expedient the birth rate might, by drawing on this reserve of reproductive power, be actually doubled. On the other hand, as an increase would follow the earlier marriage of girls, so a scarcity of employment tending to delay it for even a few years, would without any reduction of the number of marriages or restriction of families, retard the growth of the population by lengthening the interval between each generation.

AGE.	MALES.			
	Of 1,000,000 Born, the Number Surviving at the End of each Year of Life.		Mean After-lifetime (Expectation of Life).	
	1838—54.	1871—80.	1838—54.	1871—80.
Column.	1.	2.	3.	4.
0	1,000,000	1,000,000	39·91	41·35
1	836,405	841,417	46·65	48·05
2	782,626	790,201	48·83	50·14
3	754,849	763,737	49·61	50·86
4	736,845	746,587	49·81	51·01
5	723,716	734,068	49·71	50·87
6	713,881	726,815	49·39	50·38
7	706,156	721,103	48·92	49·77
8	699,688	716,309	48·37	49·10
9	694,346	712,337	47·74	48·37
10	689,857	708,990	47·05	47·60
11	685,982	706,146	46·31	46·79
12	682,512	703,595	45·54	45·96
13	679,256	701,200	44·76	45·11
14	676,057	698,840	43·97	44·26
15	672,776	696,419	43·18	43·41
16	669,296	693,695	42·40	42·58
17	665,529	690,746	41·64	41·76
18	661,402	687,507	40·90	40·96
19	656,868	683,941	40·17	40·17
20	651,903	680,033	39·48	39·40
21	646,502	675,769	38·80	38·64
22	641,028	671,344	38·13	37·89
23	635,486	666,754	37·46	37·15
24	629,882	661,997	36·79	36·41
25	624,221	657,077	36·12	35·68
26	618,503	651,998	35·44	34·96
27	612,731	646,757	34·77	34·24
28	606,906	641,353	34·10	33·52
29	601,026	635,778	33·43	32·81
30	595,089	630,038	32·76	32·10
31	589,094	624,124	32·09	31·40
32	583,036	618,056	31·42	30·71
33	576,912	611,827	30·74	30·01
34	570,716	605,430	30·07	29·33

AGE.	FEMALES.			
	Of 1,000,000 Born, the Number Surviving at the End of each Year of Life.		Mean After-lifetime (Expectation of Life).	
	1838—54.	1871—80.	1838—54.	1871—80.
Column.	5.	6.	7.	8.
0	1,000,000	1,000,000	41·85	44·62
1	865,288	871,266	47·31	50·14
2	811,711	820,480	49·40	52·22
3	782,990	793,359	50·20	52·99
4	764,060	775,427	50·43	53·20
5	750,550	762,622	50·33	53·08
6	740,584	755,713	50·00	52·56
7	732,771	750,276	49·53	51·94
8	726,116	745,631	48·98	51·26
9	720,537	741,727	48·35	50·53
10	715,769	738,382	47·67	49·76
11	711,581	735,405	46·95	48·96
12	707,770	732,697	46·20	48·13
13	704,155	730,122	45·44	47·30
14	700,581	727,571	44·66	46·47
15	696,917	724,956	43·90	45·63
16	693,050	722,084	43·14	44·81
17	688,894	718,993	42·40	44·00
18	684,378	715,622	41·67	43·21
19	679,463	711,946	40·97	42·43
20	674,119	707,949	40·29	41·66
21	668,345	703,616	39·63	40·92
22	662,474	699,141	38·98	40·18
23	656,509	694,521	38·33	39·44
24	650,463	689,759	37·68	38·71
25	644,342	684,858	37·04	37·98
26	638,148	679,822	36·39	37·26
27	631,891	674,661	35·75	36·54
28	625,575	669,372	35·10	35·83
29	619,201	663,959	34·46	35·11
30	612,774	658,418	33·81	34·41
31	606,296	652,747	33·17	33·70
32	599,769	646,957	32·53	33·00
33	593,196	641,045	31·88	32·30
34	586,575	635,003	31·23	31·60

AGE.	MALES.			
	Of 1,000,000 Born, the Number Surviving at the End of each Year of Life.		Mean After-lifetime (Expectation of Life).	
	1838—54.	1871—80.	1838—54.	1871—80.
Column.	1.	2.	3.	4.
35	564,441	598,860	29·40	28·64
36	558,083	592,107	28·73	27·96
37	551,634	585,167	28·06	27·29
38	545,084	578,019	27·39	26·62
39	538,428	570,656	26·72	25·96
40	531,657	563,077	26·06	25·30
41	524,761	555,254	25·39	24·65
42	517,734	547,288	24·73	24·00
43	510,567	539,161	24·07	23·35
44	503,247	530,858	23·41	22·71
45	495,770	522,374	22·76	22·07
46	488,126	513,702	22·11	21·44
47	480,308	504,836	21·46	20·80
48	472,306	495,761	20·82	20·18
49	464,114	486,479	20·17	19·55
50	455,727	476,980	19·54	18·93
51	447,139	467,254	18·90	18·31
52	438,099	457,022	18·28	17·71
53	428,801	446f510	17·67	17·12
54	419,256	435,729	17·06	16·53
55	409,460	424,677	16·45	15·95
56	399,408	413,351	15·86	15·37
57	389,088	401,740	15·26	14·80
58	378,481	389,827	14·68	14·24
59	367,570	377,591	14·10	13·68
60	356,330	365,011	13·53	13·14
61	344,744	352,071	12·96	12·60
62	332,789	338,820	12·41	12·07
63	320,451	325,256	11·87	11·56
64	307,720	311,368	11·34	11·05
65	294,588	297,156	10·82	10·55
66	281,064	282,638	10·32	10·07
67	267,160	267,829	9·83	9·60
68	252,901	252,763	9·36	9·14
69	238,328	237,487	8·90	8·70

AGE.	FEMALES.			
	Of 1,000,000 Born, the Number Surviving at the End of each Year of Life.		Mean After-lifetime (Expectation of Life).	
	1838—54.	1871—80.	1838—54.	1871—80.
Column.	5.	6.	7.	8.
35	579,908	628,842	30·59	30·90
36	573,192	622,554	29·94	30·21
37	566,431	616,144	29·29	29·52
38	559,619	609,599	28·64	28·83
39	552,758	602,924	27·99	28·15
40	545,844	596,113	27·34	27·46
41	538,876	589,167	26·69	26·78
42	531,849	582,104	26·03	26·10
43	524,765	574,919	25·38	25·42
44	517,617	567,612	24·72	24·74
45	510,403	560,174	24·06	24·06
46	503,122	552,602	23·40	23·38
47	495,768	544,892	22·74	22·71
48	488,339	537,043	22·08	22·03
49	480,833	529,048	21·42	21·36
50	473,245	520,901	20·75	20·68
51	465,572	512,607	20·09	20·01
52	457,814	504,188	19·42	19·34
53	449,966	495,645	18·75	18·66
54	442,027	486,973	18·08	17·98
55	433,331	477,440	17·43	17·33
56	424,239	467,443	16·79	16·69
57	414,761	456,992	16.17	16·06
58	404,895	446,079	15·55	15·45
59	394,636	434,695	14·94	14·84
60	383,974	422,835	14·34	14·24
61	372,859	410,477	13·75	13·65
62	361,387	397,644	13·17	13·08
63	349,436	384,319	12·60	12·51
64	337,031	370,495	12·05	11·96
65	324,165	356,165	11·51	11·42
66	310,833	341,326	10·98	10·90
67	297,048	325,988	10·47	10·39
68	282,819	310,170	9·97	9·89
69	268,177	293,899	9·48	9·41

AGE.	MALES.			
	Of 1,000,000 Born, the Number Surviving at the End of each Year of Life.		Mean After-lifetime (Expectation of Life).	
	1838—54.	1871—80.	1838—54.	1871—80.
Column.	1.	2.	3.	4.
70	223,490	222,056	8·45	8·27
71	208,453	206,539	8·03	7·85
72	193,297	190,971	7·62	7·45
73	178,114	175,449	7·22	7·07
74	163,003	160,074	6·85	6·70
75	148,076	144,960	6·49	6·34
76	133,453	130,227	6·15	6·00
77	119,251	115,986	5·82	5·68
78	105,592	102,359	5·51	5·37
79	92,587	89,449	5·21	5·07
80	80,343	77,354	4·93	4·79
81	68,946	66,153	4·66	4·51
82	58,471	55,842	4·41	4·26
83	48,970	46,489	4·17	4·01
84	40,471	38,132	3·95	3·58
85	32,979	30,785	3·73	3·56
86	26,476	24,436	3·53	3·36
87	20,926	19,054	3·34	3·17
88	16,268	14,576	3·16	2·99
89	12,428	10,926	3·00	2·82
90	9,321	8,015	2·84	2·66
91	6,859	5,748	2·69	2·51
92	4,946	4,025	2·55	2·37
93	3,492	2,749	2·41	2·24
94	2,411	1,828	2·29	2·12
95	1,628	1,183	2·17	2·01
96	1,071	742	2·06	1·90
97	688	452	1·95	1·81
98	430	266	1·85	1·72
99	262	151	1·76	1·65
100	154	82	1·68	1·61

AGE.	FEMALES.			
	OF 1,000,000 BORN, THE NUMBER SURVIVING AT THE END OF EACH YEAR OF LIFE.		MEAN AFTER-LIFETIME (EXPECTATION OF LIFE).	
	1838—54.	1871—80.	1838—54.	1871—80.
Column.	5.	6.	7.	8.
70	253,161	277,225	9·02	8·95
71	237,822	260,207	8·57	8·50
72	222,230	242,934	8·13	8·07
73	206,464	225,497	7·71	7·65
74	190,620	208,003	7·31	7·25
75	174,800	190,566	6·93	6·87
76	159,126	173,316	6·56	6·51
77	143,722	156,392	6·21	6·16
78	128,711	139,927	5·88	5·82
79	114,229	124,065	5·56	5·50
80	100,394	108,935	5·26	5·20
81	87,323	94,662	4·98	4·90
82	75,119	81,305	4·71	4·63
83	63,862	68,966	4·45	4·37
84	53,615	57,723	4·21	4·12
85	44,419	47,631	3·98	3·88
86	36,284	38,710	3·76	3·66
87	29,202	30,958	3·56	3·46
[illegible]	23,135	24,338	3·36	3·26
89	18,027	18,788	3·18	3·08
90	13,802	14,225	3·01	2·90
91	10,376	10,553	2·85	2·74
92	7,650	7,658	2·70	2·58
93	5,526	5,429	2·55	2·44
94	3,908	3,756	2·42	2·30
95	2,704	2,533	2·29	2·17
96	1,827	1,661	2·17	2·11
97	1,204	1,057	2·06	2·03
98	774	653	1·96	1·83
99	483	389	1·86	1·73
100	295	225	1·76	1·62

Summary of Chapter XIX.

In no department of statistics are there so many sources of fallacy as in this, for crude facts as recorded are the most fallacious of data, and no safe conclusion can be drawn as to the health of a community without an accurate knowledge of all its conditions.

The number of the population, with other facts, is ascertained by the decennial census. For the intervening year it is estimated by assuming a constant increase as in the preceding decade. But the rate is rarely uniform, the population is most frequently overestimated and the death rates, &c., appear lower than they are.

$$\text{Mean age at death} = \frac{\text{Sum of ages at death}}{\text{Number of deaths}}$$

$$\text{Mean duration of life} = \frac{\text{Number of living}}{\text{Number of deaths in a year}}$$

are true only of a population where births exactly balance deaths. Natural increase, *i.e.*, excess of births over deaths, falsifies them. Only correct estimate is the probable duration of life = the period in which a generation born in the same year has been reduced to one half.

Correction of death rates. Like can be fairly compared only with like. Since the great majority of deaths occur in childhood and old age, the death rate of a community will depend more on the proportion of children and old people, especially of young children, than on the general health.

All death rates must be reduced to a common basis, a standard population, viz., that of the entire nation.

There are thus besides the recorded death rate two others, viz.,

The Corrected, or that at which under actual conditions the people would die if they were constituted as regards sex and ages as the entire nation, and

The Standard, or that at which, constituted as they are, they would die if their sanitary conditions were the same as those of the country as a whole. The ratio between births and deaths explains numerous misconceptions, and may lead to paradoxical and in the future unexpected results.

All death rates of particular ages, classes, &c., must be calculated on the number living of that age or class, not on the whole population or total deaths; and so, too, of deaths from diseases peculiar to certain ages, as scarlatina to children under

10, if comparisons are made between communities. A study of the mean annual death rate for each quinquennium since 1860 shows a decrease in those from every infectious and preventible disease, except measles and whooping cough, which are not amenable to sanitation, and diphtheria with which other influences are concerned.

Only the highly trained statistician can appreciate the difficulties and limitations of inquiries into the mortalities of armies, &c., prisons, hospitals and the like.

Healthiness and mortality of trades and occupations. The age at death is worse than useless, the only legitimate comparison being the mortality among equal numbers of like sex and age in the particular occupation and in the nation at large, and in seeking the cause of a high class-mortality *all* the conditions of that class not common to the entire population must be considered. Even then there are numerous sources of error, and the influence of marriage falsifies all conclusions respecting females.

The birth rate is regulated by individual and social action, even without artificial restrictions being greatly dependent on the marriage rate, as that is on the labour market. Early marriages may or may not bring larger families, but they increase the population by reducing the intervals between successive generations, and a high birth rate tends, if continued, and the mortality in childhood do not exceed 50 per cent., to lower the death rate by increasing the proportion of young adults.

Infant mortality is mainly a question of feeding and care, and is closely involved with that of the employment of married women.

The birth rate, together with the infant mortality, determines the age constitution of a population, and a larger proportion of old persons is no evidence of a general longevity, but only of a low birth rate or number of children.

Without the "correction" of the age constitution immigration may conceal an actual decrease of the population through excess of deaths over births.

QUESTIONS ON CHAPTER XIX

1. What are the seven principal zymotic diseases of the Registrar General? What is the average death rate from them in the large towns of England? How is it calculated? What are the special methods of prevention in each of these diseases? 1884, II.

2. What is meant by the "Mean age at Death" of a population? How far is it a good test of sanitary conditions? How may it be approximately calculated from the birth rate and death rate? How is the general death rate calculated, making allowance for increase of population since the last census? 1885,H.

3. What is the law of increase of a population? How is its probable future increase calculated? If the census population of a town was 31,563 in 1871 and 39,482 in 1881, show how you would proceed to calculate the population for midsummer 1886. 1886,H.

4. What is meant by a Life Table? How is it constructed? What are the effects of (1) a high birth-rate, and (2) emigration and immigration on the death-rate of a town? 1887,H.

5. How should the death-rate of a town be calculated for the present year? How far are death-rates useful as indications of the healthiness of a place? The death rate of England was 20 per 1,000 in 1884. State approximately how the various classes of diseases contributed to form that number. 1889,H.

6. What is meant by each of the following expressions and how are they calculated? (1) Enumerated and (2) estimated populations. (3) Recorded, (4) standard, and (5) corrected death-rates; (6) the factor for correction; (7) mean duration of life?

7. How are populations estimated for the years intervening between one census and the next? What rough check do local authorities sometimes apply? What social and industrial conditions determine the increase or decrease of a population falsifying the assumption of uniform increase?

8. Give some striking disillusions based on over estimated populations. What effect have such inaccurate estimates on the apparent or assumed death-rate?

9. In one community there is but one person over sixty years of age in 20 of the total population: in another, one in 10 is over that age. Does it follow that the latter are the longer lived, or that the probabilities of an individual attaining that age are any greater? If not, explain the apparent paradox and give the most probable cause of the paucity of old persons in the former community, the suggestion of emigration or immigration being excluded.

10. What is the influence of age and sex constitution on the death-rate of a community? In what class of populations does the death-rate appear lower, and in what higher than it should be represented?

11. Roughly in every 1,000 of the population 140 are under 5 years of age, and 570 between 5 and 35 years: the average

death-rate of the former being 63 per 1,000 living at that age, and of the latter, 6·7. Discuss the degrees of truth and of error involved in the assertion that a "high birth-rate involves a high death-rate," and that the latter acts as a natural check on excessive growth of a population. Show that a high birth continued for ten years or more should have the effect of lowering the general death-rate.

12. In correcting or revising local death-rates, what deaths may be omitted and what additions should such omissions impose?

13. Is any good purpose served by lumping together as the "zymotic mortality" deaths from filth diseases as typhoid and diarrhœa, and such as scarlatina and measles?

14. What fallacies are involved in stating the deaths at a special age period, or from a special disease as a proportion of the total deaths from all causes, when such statements are used for purposes of comparison with other communities? Give two illustrative examples. 1891,H.

15. Show the absurdity of calculating the deaths of infants on the total population. What should be done with these, and when the means exist with deaths of persons over 60? Is the "1,000 births" convertible with a "1,000 infants living" under one year?

16. Point out the fallacy involved in calculating the scarlatina mortality, confined as it is practically to children, on the total general population, when those under 10 years constitute 24 per cent. of the population of London and Berlin, and 12 per cent. only of that of Paris.

17. What is meant by hospital mortalities? on what circumstances are they more dependent than on medical and surgical skill? When only can they be fairly used for comparison?

18. Point out some of the fallacies involved in calculations of the death-rates of armies at home and abroad.

19. The factor for correction calculated from the sex and age constitution of a population neutralises the disturbing influence of a large immigration of young adults to an industrial centre. Can the like result be attained as regards domestic servants, and if not, why?

20. Explain the terms "mean error" and "probable error" of a series of observations. Give examples. 1892,H.

21. Explain the terms "mean duration of life" and "expectation of life." How are they calculated, and what are their respective values as tests of the health of a people? What is the most accurate method of estimating the increased population? 1893,H.

22. What principles should guide us in the collection and tabulation of statistics? What are the purposes of a census? How far and under what circumstances is the death-rate a good test of the health of a community? What do you understand by "recorded," "standard" and "corrected" death-rates, and how are the latter obtained? 1894, H.

23. What is the average death-rate in the large towns of England from the principal "zymotic" diseases? How are these calculated and what are the special methods of prevention in each of these diseases? 1895, H.

24. What fallacies have to be guarded against in using mortality statistics for comparative purposes? Point out and explain the error or fallacy (if any) existing in the following statistical statements.

(*a*) Four hundred and twenty persons sicken with a certain disease; of these 160 die, therefore the average death-rate in that disease is 38 per cent. (*b*) A district containing 125,000 persons has a death-rate of 20 per 1,000; an adjoining district containing 14,500 has a death-rate of 14 per 1,000, therefore the combined death-rates of these districts is 17 per 1,000. 1896, H.

25. Point out some of the chief fallacies met with in anti-vaccination literature, the actual figures being assumed to be correct.

26. Discuss the fallacies into which persons constantly fall in drawing arguments from the mortality, actual or relative, of different occupations, especially those connected with the duration of the employment and the plurality of unfavourable conditions. Of what value is the mean age at death?

27. What is the influence of birth-rates on death-rates? How is the birth-rate estimated, and what influence do agricultural and industrial life exert on it? 1899, H.

28. What do you understand by "comparative mortality figures"? How are they usually calculated? 1900, H.

29. Point out the fallacies in the statements:

(*a*) Generals, bishops, judges and pensioners are remarkable for their longevity.

(*b*) The mean age at death of pilots and light-house keepers is higher than that of seamen.

(*c*) The early age at death, and the high comparative mortality of barmaids are evidence of the injurious effects of excessive indulgence in alcohol.

(*d*) The married of both sexes live longer than the unmarried, showing that marriage is conducive to health.

(*e*) Whatever may be urged against the practice of limitation

of families, the larger proportion of old persons in France than in England and in Germany shows that it is favourable to the health and longevity of the population.

30. Comment on the statement that the death-rate is determined by sanitary conditions, the birth-rate by industrial and economic.

31. "Is it possible to induce a more rapid increase of the population, or to check the rate of increase to a considerable extent without any change in the proportion of women marrying, or in the number of children to each marriage?" Explain this statement.

32. How may improved sanitation and social well-being conduce to the increase of cancer in a community, while reducing the mortality from tuberculosis, scarlatina, diphtheria, diarrhœa, measles, and enteric fever?

33. Show that the high mortality of infants in towns is not the result of poverty alone.

34. Explain the statement that with the present falling birth-rate, improved sanitation may lead in the next generation to an increase in the death-rate which it has been declining for the last thirty years.

35. What did Dr. Rumsey mean by "lines of vitality and of mortality," and what was the true meaning of Dr. Farr's "healthy and unhealthy districts"?

PART VI

METEOROLOGY

CHAPTER XX

Temperature

It would be quite impossible in the space at our disposal to attempt anything like an explanation of the causes of and the laws governing the various meteorological phenomena of barometric and thermometric variations, rainfall, humidity, and winds, all of which are inseparably entangled one with the other. Suffice it here to say, that it is not chance but a complex association of causes in which the chief factor is the rotation of the earth on its axis, exposing successively to the sun's rays portions of its surface differing in the distribution of sea and land, and in the elevation and characters of the latter; masses of air being thus variously warmed and taking up different quantities of water, while the expansion and rising of the warmed air sets up currents in the surrounding atmosphere, which are deflected by the progressive retardation of the velocity of the revolution of the globe from the equator to the poles and disturbed by contact with mountain ranges or by passage over seas or arid plains.

Where there is no matter there can be no conduction, though heat may be radiated through space, The sun's rays, therefore, warm the objects on which they fall, though not the intervening space.

The temperature of the air is not due to the mere

passage through it of the sun's rays, but to the conversion of these by impact with the land or water into obscure rays, which then warm by conduction the air in contact with them. That space is incapable of being warmed by the sun's rays, and air very imperfectly, is shown by the intense cold observed at high altitudes in balloon ascents, and the perpetual snow on the summits of mountains.

Again, reflection and absorption are complementary. What heat is not reflected is absorbed, and is given off again by radiation, which is, therefore, always equal to absorption, but proceeds more or less rapidly as the temperature of the radiating body differs more or less from that of the surrounding medium. Snow thus reflects nearly the whole of the sun's rays as it receives them without being melted ; clear skies and bright suns are indeed anything but conducive to a thaw. As a rule polished surfaces and light colours reflect, while rough surfaces and dark colours absorb and radiate heat. Thus, the colour of the soil is not without its influence on the local climate.

Comparison between Scales of Fahrenheit, Réaumur, and the Centigrade.

Freezing point = 32° F. = 0° C. = 0° R.; Boiling point = 212° F. = 100° C. = 80° R. To convert degrees Centigrade or Réaumur into degrees Fahrenheit, or *vice versâ*, use one of the following formulæ :

Let F. = Number of degrees Fahrenheit, C. = Number of degrees Centigrade, and R. = Number of degrees Réaumur, then :—

$$F = \frac{9C}{5} + 32 \qquad F = \frac{9R}{4} + 32 \qquad 5R = 4C$$

$$C = \frac{5(F-32)}{9} \qquad R = \frac{4(F-32)}{9}$$

Comparison between Scales of Fahrenheit, Réaumur, and the Centigrade.

CENT.	FAH'T.	RMR.	CENT.	FAH'T.	RMR.
100°B.	212°B.	80°B.	60°	140°	48°
99	210·2	79·2	59	138·2	47·2
98	208·4	78·4	58	136·4	46·4
97	206·6	77·6	57	134·6	45·6
96	204·8	76·8	56	132·8	44·8
95	203	76	55	131	44
94	201·2	75·2	54	129·2	43·2
93	199·4	74·4	53	127·4	42·4
92	197·6	73·6	52	125·6	41·6
91	195·8	72·8	51	123·8	40·8
90	194	72	50	122	40
89	192·2	71·2	49	120·2	39·2
88	190·4	70·4	48	118·4	38·4
87	188·6	69·6	47	116·6	37·6
86	186·8	68·8	46	114·8	36·8
85	185	68	45	113	36
84	183·2	67·2	44	111·2	35·2
83	181·4	66·4	43	109·4	34·4
82	179·6	65·6	42	107·6	33·6
81	177·8	64·8	41	105·8	32·8
80	176	64	40	104	32
79	174·2	63·2	39	102·2	31·2
78	172·4	62·4	38	100·4	30·4
77	170·6	61·6	37	98·6	29·6
76	168·8	60·8	36	96·8	28·8
75	167	60	35	95	28
74	165·2	59·2	34	93·2	27·2
73	163·4	58·4	33	91·4	26·4
72	161·6	57·6	32	89·6	25·6
71	159·8	56·8	31	87·8	24·8
70	158	56	30	86	24
69	156·2	55·2	29	84·2	23·2
68	154·4	54·4	28	82·4	22·4
67	152·6	53·6	27	80·6	21·6
66	150·8	52·8	26	78·8	20·8
65	149	52	25	77	20
64	147·2	51·2	24	75·2	19·2
63	145·4	50·4	23	73·4	18·4
62	143·6	49·6	22	71·6	17·6
61	141·8	48·8	21	69·8	16·8

Comparison between Scales of Fahrenheit, Réaumur, and the Centigrade (continued.)

CENT.	FAH'T.	RMR.	CENT.	FAH'T.	RMR.
20°	68°	16°	15°	5°	12°
19	66·2	15·2	16	3·2	12·8
18	64·4	14·4	17	1·4	13·6
17	62·6	13·6	18	−0·8	14·4
16	60·8	12·8	19	2·2	15·2
15	59	12	20	4	16
14	57·2	11·2	21	5·8	16·8
13	55·4	10·4	22	7·6	17·6
12	53·6	9·6	23	9·4	18·4
11	51·8	8·8	24	11·2	19·2
10	50	8·0	25	13	[illegible]
9	48·2	7·2	26	14·8	20·8
8	46·4	6·4	27	16·6	21·6
7	44·6	5·6	28	18·4	22·4
6	42·8	4·8	29	20·2	23·2
5	41	4	30	22	24
4	39·2	3·2	31	23·8	24·8
3	37·4	2·4	32	25·6	25·6
2	35·6	1·6	33	27·4	26·4
1	33·8	0·8	34	29·2	27·2
Zero.	32	Zero.	35	31	28
1	30·2	0·8	36	32·8	28·8
2	28·4	1·6	37	34·6	29·6
3	26·6	2·4	38	36·4	30·4
4	24·8	3·2	39	38·2	31·2
5	23	4	40	40	32
6	21·2	4·8	41	41·8	32·8
7	19·4	5·6	42	43·6	33·6
[illegible]	17·6	6·4	43	45·4	34·4
9	15·8	7·2	44	47·2	35·2
10	14	[illegible]	45	49	36
11	12·2	8·8	46	50·8	36·8
12	10·4	9·6	47	52·6	37·6
13	8·6	10·4	48	54·4	38·4
14	6·8	11·2	49	56·2	39·2

The Barometer

By barometic pressure we mean the weight of a column of air at any given time and place expressed in terms of the height of a column of mercury of the same weight, as indicated by the barometer, reduced by calculation to what it would be at the sea-level and at a temperature of zero (freezing point) to facilitate comparisons. The barometer is not a weather-glass; it is simply a balance for weighing the air, whatever inferences local observation may enable one to draw from its readings taken alone or in combination with other circumstances. The pressure of the atmosphere in its higher regions is, of course, less than below, and the barometer, therefore, gives a lower reading the more elevated the situation. The depression of the mercury amounts to about one-thousandth of an inch for every foot of altitude, and the barometer may thus be used for calculating heights. In the Engadine, for example, the mercurial column is five inches lower than in the plains, and in ordinary barometers would sink below the scale.

Ordinary hall barometers are useless for scientific observations, being unprovided with means for adjusting the levels of the mercury in either column.

Aneroids are unsurpassable as regards sensitiveness and accuracy, and need no such adjustment or correction for temperature, but are too liable to get out of order to be trustworthy for long.

A "Standard" barometer, in which alone the level of the mercury in the cistern, *i.e.*, the foot of the mercurial column, can always be made to coincide with the zero of the scale, and in which the scale is marked on the tube or on a brass rod, not on or mounted on the wooden frame, should be hung perfectly perpendicularly in a place sheltered from sun and rain, but in a good light.

Reading and Correction.

To read the barometer.—First note the temperature, before the warmth of the observer's body can affect the thermometer. Then adjust the cistern by working the screw beneath it up-

wards or downwards until the point of the ivory peg meets its image on the surface of the mercury in the cistern, this point indicating the position of the zero whence the scale is graduated. Gently tap the barometer twice or thrice so as to overcome any adhesion of the mercury to the glass, and standing with the eye on a level with the upper end of the column, adjust the vernier so that its lower margin just shuts off the light above the summit of the curved surface of the mercury If (Fig. 38 A) this correspond exactly with a line on the scale the observation is complete ; if not, note the line on the scale next below, and then following the marks on the vernier upwards note the first which coincides with one on the scale. Each figure on the vernier represents $\frac{1}{100}=0·01$ inch, and each division $\frac{2}{1000}=\frac{1}{500}=0·002$ inch, which together indicate the exact value of the excess of height over the next lower mark on the scale.

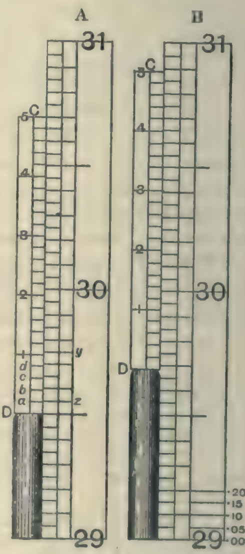


FIG. 38.

Thus in Fig. B, the mercury stands a fraction above 29·650 inches on the scale, and the vernier having been adjusted, the line that coincides with one on the scale is the third above the figure 3, *i.e.*, 0·036 is to be added to the 29·650, giving 29·686 as the correct reading. Sometimes two consecutive lines on the vernier may *appear* to coincide with two on the scale, the intermediate odd thousanth is then to be taken as the correct reading : thus in this case had the third and fourth lines *seemed* so to coincide with lines on the scale, the reading would have been the mean of 29·686 and 29·688, *i.e.*, 29·687. [The vernier being divided into twenty-five parts, together equal to twenty-four of the smallest divisions of the scale (viz. 0·05 inch), each of the former is less than one of the latter by $\frac{1}{25}$, *i.e.*, by $\frac{1}{25}\times\frac{1}{20}=\frac{1}{500}$ $=0·002$ inch.] The index error, if any, and the correction for

capillarity, are marked for every half inch on Kew certificates. Correction for temperature, by which all readings are reduced to what they would be at 0° C. (32° F.), is calculated from the coefficients of expansion of mercury and of brass, the material of the scale, by Schuhmacher's formula.

The results, as applied to barometers with brass scales extending from the cistern to the top of the tube, are given in the table following for 27 and 30 inches and for every 10° F. Corrections for intermediate heights and temperatures may be found by proportional parts with approximate accuracy.

Temp.	27 in.	30 in.	Temp.	27 in.	30 in.	Temp.	27 in.	30 in.
0	+ ·069	+ ·077	40	− ·028	− ·031	80	− ·124	− ·138
28	+ ·001	+ ·001	50	− ·052	− ·058	90	− ·148	− ·164
29	− ·001	− ·001	60	− ·076	− ·085	100	− ·172	− ·191
30	− ·004	− ·004	70	− ·100	− ·111			

Correction for altitude.—The mercury falls approximately $\frac{1}{1000}$ inch = 0·001 inch for each foot above the sea-level. But this varies a little with the temperature and pressure. The following table gives the *addition* in inches at 30 and 27 inch pressure and 0° 40° and 80° F. for 10, 100 and 1,000 feet of altitude. Intermediate heights are calculated proportionately. The sea-level at Liverpool mid-tide is the ordnance standard.

Height in feet.	Temperature of external air.		
	0° F.	40° F.	80° F.
When the	Barometer at	sea-level reads	30 inches.
10	·012	·011	·010
100	·123	·112	·103
1000	1·208	1·105	1·017
When the	Barometer at	sea-level reads	27 inches.
10	·011	·010	·009
100	·111	·101	·093
1000	1·087	·994	·915

But besides this there are other and variable causes of alteration in atmospheric pressure. Warm air is lighter than cold, and watery vapour is lighter than air; the barometer, therefore, falls with warm moist westerly winds and rises with cold dry easterly ones, not from any faculty of predicting rain or drought.

THERMOMETERS

The thermometers required are—

1. Shade maximum thermometer.
2. Shade minimum ,,
3. Solar radiation ,,
4. Terrestrial radiation ,,

Shade thermometers are best mounted in a hut of stout boards, with a ridge roof, louvred sides, open below and raised on four posts three to four feet from the ground. The box should be at least four feet square, with a door on the side least exposed to the sun. It should be put up where it will be freely exposed to the movement of the air, but so far as possible sheltered from direct sunshine or radiation from a wall, *e.g.*, on the north side of and at about ten to twenty feet from the house.

They should all be self-registering, and it is well to have their bulbs carried beyond the frames.

The solar radiation thermometer has its bulb blackened, and it is inclosed in a glass cylinder from which the air has been exhausted. It should be fixed to a post about four feet above the ground, where it will be exposed to the full rays of the sun all day.

The terrestrial radiation or "grass minimum" should be mounted on a low tripod just above but not touching a grass plot, or if snow be on the ground then in the snow. Scott recommends a black board in preference to the grass.

They should all read to tenths of a degree marked on the glass itself.

The shade temperature should be taken at least twice a day 9 a.m. and 3 p.m.

The maximum and minimum thermometers are usually read early in the morning, and the maximum entered as if reached in the previous afternoon. But it would be better to read them both morning and evening, since in winter the maximum temperature may occur in the morning and the minimum in the afternoon, being determined rather by the wind and clouds than by the hour of the day.

The mean of the maximum and minimum shade temperatures of each day does not truly represent the mean temperature. Herschell gives the following formulæ—

If observations are taken at 7 a.m., 2 p.m., and 9 p.m., or t, t′, and t″, then

$$\frac{t+t'+2t''}{4} = \text{mean temperature of day.}$$

If at 8 a.m., 3 p.m., and 10 p.m.—

$$\frac{7t+7t'+10t''}{24} = \text{mean temperature of day.}$$

Winds

Of course the aggregate weight of the earth's atmosphere is constant, and local variations are compensated by opposite ones elsewhere. These disturbances in equilibrium set up movements among unequally heated and lighter or heavier masses of air which we call winds. Among the factors concerned in the causation of winds are the rotation of the earth and consequent successive exposure of different parts of its surface to the sun's rays, the saturation of the air in passing over water due to evaporation, and its heating or cooling by the land over which it blows, with the effects of mountains in diverting these air streams, cooling them and throwing down their vapour as rain or snow.

Direction.

The vane must be put up where it will be unaffected by eddies, horizontal or vertical, and care be taken that it is adjusted to the true meridian, for the needle at the present time points west of the north, 19° in the S.E. of England and 25° in the N.W. of Ireland, the lines of equal variation running N.N.E. and S.S.W. It is sufficient to register the wind as N., N.E., E., S.E., S., S.W., W., and N.W., but any change during the day must be noted.

Except in certain parts of the world an absolute calm is rare. In this country the wind usually travels at a rate of ten to thirty miles an hour. Anything between forty and seventy miles is called a gale, and over this a storm or hurricane. But it must be borne in mind that these figures as they appear in weather reports represent the whole distance covered in an hour, and are useful only in calculating the progress of a storm. For engineering purposes the maximum force of the wind at any moment has to be considered, and a wind blowing at

the rate of forty miles per hour will at one moment be at that of ten and at another of eighty or more. The velocity of the wind is ascertained by anemometers, small instruments constructed on the principle of the windmill, of which Dr. Robinson's or Casella's anemometers are most used. In Robinson's the wind is received on four cups which work a dial, the larger the cups the more correct the readings. Osler's, which registers the direction and the velocity, is a large and beautiful instrument.

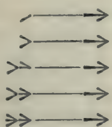
The pressure is determined by the anemometers of Osler or of Cator, in which a pencil records the pressure exerted by the wind on plates. Osler's is worked by springs, Cator's by levers, an objection to the former being that the springs are in time affected by exposure to the atmosphere. The indications, however, vary with the size of the plates, those having a surface of one square foot being usually employed.

It was formerly the practice to assume that the register indicated one-third of the true velocity, but Professor Stokes findst hat with Robinson's anemometer, as used by the Meteorological Society, having cups nine inches in diameter on arms twenty-four inches long, the factor must be 2·4. Sir F. James gives the formula $P = v^2 \times 0{\cdot}005$ for calculating the pressure from the velocity v being the velocity in miles per hour, and P the pressure in lbs. per square foot, the pressure varying as the square of the velocity.

Beaufort's scale adopted by the Meteorological Office, with the velocities indicated by each number, and Schott's corrected estimates, is shown in the table following.

Force.	Velocity in miles per hour.			
	Beaufort.		Schott.	
0	Calm	3	0	Very different.
1	Light air	8	1	
2	Light breeze	13	4	
3	Gentle ,,	18	10	
4	Moderate ,,	23	17	Approximately the same.
5	Fresh ,,	28	24	
6	Strong ,,	34	32	
7	Moderate gale	40	40	
8	Fresh ,,	48	48	
9	Strong ,,	56	56	
10	Whole ,,	65	67	
11	Storm	75	82	
12	Hurricane	90	100	

In the compilation of weather-maps the direction of the winds is indicated by arrows, and the force by the number of pinnæ from one to five, thus, to take the table from the weather charts of the U.S.A. Signal Office.

Symbol.	Force.	Velocity.	
		Miles per hour.	Metres per second.
	1, 2	0 to 9·0	0 to 4·0
	3, 4	9·1 to 22·5	4·1 to 10·0
	5, 6	22·6 to 40·5	10·1 to 18·0
	7, 8	40·6 to 67·5	18·1 to 30·0
	9, 10	67·6 and upwards	30·1 and over

The following table of velocities, pressure, and character will be found probably more accurate and generally useful on land.

Velocity and Pressure of Wind.

Miles per hour.	Feet per minute.	Feet per second.	Pressure (direct) in lbs. per square foot.	Description.
1	88	1·47	·005	Hardly perceptible.
2	176	2·93	·020	Just perceptible.
3	264	4·4	·044	
4	352	5·87	·079	Gentle breeze.
5	440	7·33	·123	
10	880	14·67	·492	Pleasant breeze.
15	1329	22·	1·107	
20	1760	29·3	1·968	Brisk gale.
25	2200	36·6	3·075	
30	2640	44·	4·428	High wind.
35	3080	51·3	6·027	
40	3520	58·6	7·872	Very high wind.
45	3960	66·	9·963	
50	4400	73·3	12·300	Storm.
60	5280	88·	17·712	Great storm.
70	6160	102·7	24·108	
80	7040	117·3	31·488	Hurricane.
100	8800	146·6	49·200	

The velocity of the wind shows a diurnal curve from a minimum in the two hours after midnight to a maximum in the two after noon, but this is an average subject to continual variation. Also a monthly variation or annual curve, highest between December and March, and lowest between May and October, the difference being far more marked in Scotland and Ireland than in England.

The ordinary more or less rectilinear movements of the wind are perpetually varied by the passage from west to east in this hemisphere of vortices called cyclones or anticyclones. In the cyclone the wind moves in a direction opposite to that of the hands of a watch, the barometer is lowest in the centre, and the area embraced is comparatively small, the gradient or rise of atmospheric pressure from the centre to the circumference is steep, the velocity of the wind is consequently great, and the cyclone is usually attended by much rain. The passage of a cyclone is therefore often spoken of as that of a "depression" over any area. In the anticyclone the reverse of all these conditions is met with. Anticyclones, therefore, bring clear skies, gentle winds, and fine weather, hot in summer, but cold and frosty in winter.

Humidity

The quantity of watery vapour that the air can hold in a gaseous and perfectly invisible form varies with the temperature from two grains per cubic foot at freezing point to twenty grains at 100° F., rising slowly at first but more rapidly at the higher temperatures. When the air thus contains as much as, at the given temperature, it is capable of holding, it is said to be saturated; and humidity is a relative term having reference, not to the actual amount of vapour present, but to the proportion which this bears to the possible maximum at that temperature, which may be learnt from tables.

Omitting fractions, we may say that each cubic foot of air can hold—

2 grains	at	30° F.	9 grains	at	74° F.
3	,,	41°	10	,,	77°
4	,,	49°	11	,,	80°
5	,,	56°	12	,,	83°
6	,,	61°	13	,,	86°
7	,,	66°	14	,,	88°
8	,,	70°			

Degrees of humidity mean the percentage of saturation. Thus if at a temperature of 61° F. the air contained six grains per cubic foot it would be saturated ; if the temperature were suddenly raised to 83° F. the humidity would be only 50 degrees, since the air could then hold twelve grains ; but if, on the other hand, it were cooled down to 41° F. it would still be saturated, but three of the six grains would have been deposited in the liquid form. The temperature at which this deposit begins is called the dew point, which, as we have seen, is for six grains 61° F.; in other words, a dew point of 61° indicates the presence of six grains of water in each cubic foot of air. The sensations of damp and dryness depend on the degree of saturation or relative humidity, and there may be far more aqueous vapour in the air on a hot dry day in summer than on a cold damp day in winter.

The most agreeable degree of humidity is about 70 to 80 per cent. for ordinary temperatures, though 50 or even 30 degrees is not unpleasant if the air be cold, as in the Engadine, so much frequented by phthisical patients in winter. At high temperatures each extreme is painful, one by checking, the other by unduly exciting evaporation from the human body. It is on this account that persons in the Turkish bath are compelled to drink water to keep pace with the loss of fluids from the skin.

Such extreme variations as we have suggested by way of illustration are met with only in arid districts, for elsewhere as the temperature rises the relative humidity is to some extent maintained by evaporation from the land and water. Clouds, too, and even invisible vapour, resist the passage of radiant heat, whether from the sun or from the earth, checking evaporation

but moderating the heat of the sun's rays and the loss of heat from the surface of the earth, cooling the air by day in summer, but keeping the ground warmer by night and in winter, and thus preventing the deposition of dew and hoar frost. The relation between degrees of humidity of the air, evaporation from its surface, the condensation of vapour and deposit of dew, and their disappearance, may be easily studied by observing the results of watering the streets or a garden on a hot sunny day and again in the evening, and by watching the formation of a mist over a sheet of water in the evening, and the disappearance of this, as well as of the dew, when the rising sun again warms the air and enables it to take up the excess of vapour precipitated during the previous night.

Evaporation depends directly on humidity, and only indirectly on temperature, being most active when the air is relatively driest, and ceasing entirely when saturation is reached. It is not arrested even by freezing, taking place from the surface of ice no less than of water, if the air be, as it often is during prolonged frosts, relatively dry, while in hot but rainy weather it may be very small.

Humidity and evaporation are among the most important factors in the influence of climate and weather on health.

Wet and Dry Bulb Thermometers.

The only hygrometer in common use is the combination of the dry and wet bulb thermometers, the former giving the actual temperature and the latter that of evaporation, the dew point being calculated from the difference between their respective readings by means of a series of empirical factors worked out by Mr. Glaisher. The instrument is to be placed in the shade four feet above the ground, fully exposed to the air, but protected from radiant heat from walls, &c. The wet bulb is covered with muslin kept moist by twisting round it a skein of cotton, previously boiled in a solution of carbonate of soda and afterwards in ether to free it from fat, the other end of the cotton being immersed in a vessel of water. The cotton should be changed every fortnight and the water should be distilled or rain water. When the water is frozen and the syphon action arrested the muslin should be moistened with a sponge or brush and allowed to freeze again before the observation is taken, but should the temperature have risen above freezing point the muslin, &c. must be thawed with warm water, and the reading delayed till it has cooled down to the true temperature. When the air is saturated the readings of the two thermometers will be

the same, and will be that of the dew point, otherwise that of the wet bulb is always lower, though above the dew point so long as the temperature of the air is above freezing. When this is lower and the wet bulb is, as it should be, cased in ice, it will read 32°, however low the dry one may have sunk.

The two tables following give (I) the weight of a cubic foot of vapour at each temperature, or the weight which constitutes saturation, the temperature being the dew point at 30° of barometric pressure, and (II) Glaisher's factors for all temperatures of 10° F. to 100° F.

A.—*Table of Tensions and Dew-points, or Weight of Vapour constituting saturation at every degree from* 0 *F°. to* 100 *F°.*

Temp. F.°	Weight in grains of a cubic foot of Vapour.	Temp. F.°	Weight in grains of a cubic foot of Vapour.	Temp. F.°	Weight in grains of a cubic foot of Vapour.
0	0·55	34	2·30	68	7·51
1	0·57	35	2·39	69	7·76
2	0·59	36	2·48	70	8·01
3	0·62	37	2·57	71	8·27
4	0·65	38	2·66	72	8·54
5	0·68	39	2·76	73	8·82
6	0·71	40	2·86	74	9·10
7	0·74	41	2·97	75	9·39
8	0·77	42	3·08	76	9·69
9	0·80	43	3·20	77	9·99
10	0·84	44	3·32	78	10·31
11	0·88	45	3·44	79	10·64
12	0·92	46	3·56	80	10·98
13	0·96	47	3·69	81	11·32
14	1·00	48	3·82	82	11·67
15	1·04	49	3·96	83	12·03
16	1·09	50	4·10	84	12·40
17	1·14	51	4·24	85	12·78
18	1·19	52	4·39	86	13·17
19	1·24	53	4·55	87	13·57
20	1·30	54	4·71	88	13·98
21	1·36	55	4·87	89	14·41
22	1·42	56	5·04	90	14·85
23	1·48	57	5·21	91	15·29
24	1·54	58	5·39	92	15·74
25	1·61	59	5·58	93	16·21
26	1·68	60	5·77	94	16·69
27	1·75	61	5·97	95	17·18
28	1·82	62	6·17	96	17·68
29	1·89	63	6·38	97	18·20
30	1·97	64	6·59	98	18·73
31	2·05	65	6·81	99	19·28
32	2·13	66	7·04	100	19·84
33	2·21	67	7·27		

B.—*Glaisher's Factors.*

Reading of Dry Bulb. F.°	Factor the product of which into the difference between the readings of the Dry and Wet bulb thermometer deducted from the former gives the Dew point.	F.°	Factor.	F.°	Factor.
		36	2·50	69	1·78
		37	2·42	70	1·77
		38	2·36	71	1·76
		39	2·32	72	1·75
		40	2·29	73	1·74
		41	2·26	74	1·73
		42	2·23	75	1·72
10	8·78	43	2·20	76	1·71
11	8·78	44	2·18	77	1·70
12	8·78	45	2·16	78	1·69
13	8·77	46	2·14	79	1·69
14	8·76	47	2·12	80	1·68
15	8·75	48	2·10	81	1·68
16	8·70	49	2·08	82	1·67
17	8·62	50	2·06	83	1·67
18	8·50	51	2·04	84	1·66
19	8·34	52	2·02	85	1·65
20	8·14	53	2·00	86	1·65
21	7·88	54	1·98	87	1·64
22	7·60	55	1·96	88	1·64
23	7·28	56	1·94	89	1·63
24	6·92	57	1·92	90	1·63
25	6·53	58	1·90	91	1·62
26	6·08	59	1·89	92	1·62
27	5·61	60	1·88	93	1·61
28	5·12	61	1·87	94	1·60
29	4·63	62	1·86	95	1·60
30	4·15	63	1·85	96	1·59
31	3·70	64	1·83	97	1·59
32	3·32	65	1·82	98	1·58
33	3·01	66	1·81	99	1·58
34	2·77	67	1·80	100	1·57
35	2·60	68	1·79		

Use of Glaisher's Tables.

Multiply the difference between the two readings by the factor (Table B.) opposite that of the dry bulb, and deduct the product from the latter ;—the remainder will give the dew point. Then finding (Table A.) the weight of vapour corresponding to the dew point, and therefore actually present, and that which at the actual temperature would constitute saturation, the proportion which the former bears to the latter will be the degree of humidity for the time being. Thus the dry bulb reading 67° F., and the wet 62° F. gives a difference of 5°. The factor opposite 67° is 1·8, which $\times\ 5 = 9$ and $67° - 9° = 58°$ = the dew point. The

weight of vapour per cubic foot constituting saturation at 58° is 5·39 grains, and at 67° is 7·27 grains, therefore the present degree of humidity is $\frac{5{\cdot}39 \times 100}{7{\cdot}27} = 0.74$ or 74 per cent. of saturation, or 74° of humidity.

Rainfall

When masses of warmer air in the higher regions of the atmosphere charged with aqueous vapour are suddenly cooled by contact with colder currents or by impinging on cold mountain tops, their power of holding the vapour in suspension is lost, and it is condensed as clouds or falls in the form of rain or of snow, giving rise to streams which run down the sides of mountains.

We may illustrate this by one or two striking examples. The hot trade winds from the Indian Ocean, laden with vapour, first impinge on the mountainous coasts of Malabar and Coromandel, where they let fall a part of their vapour in copious rains. Then passing over the hot plateau of the Deccan and the plains of Northern Hindostan they are met by the snow-capped Himalayas, which condense the last drops, giving rise not only to the heaviest rainfall yet observed, but to the sources of the Ganges, Brahmaputra, and Indus, with their tributary rivers; after which, cold and dry, they sweep the rainless plains of Tibet.

Again, the westerly winds of the Pacific are in like manner chilled and their vapour condensed by the northern range of the great chain of the Rocky Mountains; and the contrast between the mild climate of British Columbia, with its heavy rainfall, and the cold and almost rainless region of Saskatchewan, separated from it only by the mountains in question, is remarkable.

Similar, although less marked, contrasts are presented by the western and eastern coasts of the British Isles, and of Scandinavia, much modified, however, by local circumstances. Thus in Cumberland the rainfall at Seathwaite is 113 inches annually; at Cockermouth only 22. In Wales and the west of England generally it ranges between 30 and 60 inches. At Plymouth the extremes are 45 and 100, at Exeter 31 and 90; but at Sidmouth the mean rainfall is only 20 inches, this town, like Cockermouth, escaping from some local circumstances. Near London it is 24.5, and this prevails generally in the eastern counties.

The Rainfall in England.

Order of months in the East of England.	Average rainfall in inches 1813 to 1872.			Order of months in the West of England.
	England East.	London (slightly different).	England West.	
August	2·84	2·26	5·25	November
November . . .	2·83	2·28	4·97	October
October	2·71	2·74	4·42	December
July	2·57	2·32	3·95	August
September . . .	2·55	2·35	3·72	January
May	2·11	2·07	3·54	September
June	1·95	2·01	3·46	July
January	1·89	1·91	2·86	February
December . . .	1·60	1·93	2·84	{ March
February	1·59	1·52	2 84	June }
April	1·48	1·66	2 59	{ April
March	1·40	1·52	2·59	May }
	25·52	24·55	43·03	

Rain Gauge.—The best form is that known as the Snowdon guage, consisting of a glass funnel having a diameter of 8 inches, and therefore an area of 50 square inches, let into a cylindrical copper vessel, its tube dipping into a glass cylinder having a lip for convenience in emptying it. To retain snow, which might be blown out of the funnel before it had melted, a similar cylinder, though of course open below, is fixed on to the other, so as to form a rim or wall several inches high around the funnel which it must touch closely. The water or the melted snow is, when collected, usually once a day, to be measured in an accurately graduated glass, or the receiver may be itself the measure. But the narrower the measuring glass the more accurate the estimation. Thus, if the diameter of the measure be 2½ inches, its area will be 5 square inches, or one-tenth that of the funnel, and each inch and tenth inch will represent a depth of 0·1 and 0·1 inch of rain.

The gauge should be placed about a foot from the ground in an open situation free from all eddies, with no object subtending an angle of 20°. Theoretically the elevation should not make any difference, but in practice it is found that a gauge placed on a terrace or roof shows a less amount owing to the up-current of air produced by the deflection of the wind impinging on the face of the wall.

Fogs

While the cooling agency in the production of dew is terrestrial radiation, and the absence of overhanging screens, whether of clouds or of trees, is a necessary condition, fogs are caused by the contact of masses of air of different temperatures, both, especially the warmer, charged with vapour. Such fogs appear on sea shores, especially if skirted by cliffs, over sheets of water or damp valleys and on the margins of anticyclones. Radiation fogs which are formed on land in still clear weather only are of somewhat different origin. The air on the higher ground, chilled by terrestrial radiation, rolls down the hill sides, and meeting the warmer air of the valleys, condenses the aqueous vapour which it held invisibly. As successive masses of cold air descend more vapour is condensed, and the fog appears to ascend the side of the hill. Wide low-lying plains are often seen to be covered in the evening by a sheet of fog, perhaps only a few feet deep, above which mounds and higher grounds stand like islands in a sea of mist.

Climate

Climate is the general resultant of temperature, atmospheric pressure, humidity, rainfall, and other less known factors modified by soil, aspect, and other local circumstances. We say the general resultant, for no greater error could be committed than to draw any conclusions from a comparison of mean temperatures or rainfalls. Means have well been described as general truths but particular fallacies, and it makes the greatest difference in the climate of any place, whether the meteorological means are those of wide or narrow oscillations. Thus the mean annual temperature at Algiers is 56° F., and of St. Louis 54° F., yet the climates cannot be compared, for in winter the mean temperature of St. Louis is 33° F., often descending much lower, while that of Algiers is 54° F. On the other hand the mean summer temperatures of the two are nearly the same, or 74° at Algiers and 75° at St. Louis. The range is 20° F. at Algiers and 42° F. at St. Louis between the means, and much more between the extremes of summer and winter. So, too, it

makes the greatest difference whether light rains fall on a majority of the days in the year, or seasons of drought alternate with torrents of rain during a few weeks, though the total rainfall may be the same ; or whether the sun shines continuously in summer and winter with dark weather in spring only, or cloud and sunshine are distributed equally throughout the year.

Generally speaking, proximity to the sea produces a temperate, equable, and humid climate, which is, therefore, described as insular, whereas, great extremes are met with in continental or inland districts. Thus the eastern provinces of Germany are far colder than the western, on account of their remoteness from the ocean ; and the southern colder than the northern from their greater elevation, with the chilling influence of the Alps on what otherwise would be the warm winds from the south ; and throughout Germany the extreme variations are far greater than they are here. Mountainous districts are more rainy than the plains, even when remote from the sea. Forests check percolation through the soil, and in hilly countries favour the rise of springs. By diminishing terrestrial radiation they make hot climates cooler, and increase the rainfall. The destruction of forests, on the other hand, has reduced many fertile regions, as in Palestine, to arid wastes. *Cæteris paribus*, trees tend to make the days cooler and the nights warmer, to moderate the heat in hot climates, and the cold in cold ones. Drainage of lands, combined with cultivation, tends to raise the temperature by reducing the amount of damp soil, and of evaporation, thus making a country more healthy than it was before.

Health Resorts.

Pettenkofer's witticism about people going for change of soil rather than of air, is specially true of the health resorts of this country ; for, while the composition of the atmosphere beyond the precincts of great towns is everywhere the same, there are few, if any, at altitudes

sufficient to make a perceptible difference in its pressure and density, certainly none presenting such contrasts as the Engadine and the Riviera. No single factor, or even combination of meteorological factors, suffices to explain satisfactorily the "bracing" air of some and the "relaxing" climate of other places, which will be seen to be hopelessly mixed in the following table.

	Subsoil.	Winter.	Summer.	Daily Range.	Rainfall.	Rainy Days.	Humidity.
Regent's Park	London Clay	41·6	56·9	13·8	25.16	164	80%
Margate . .	Chalk	41·8	56·4	10·9	22.98	165	81%
Lowestoft . .	Gravel	40·8	54·8	11·4	24.09	173	83%
Cromer . . .	Crag and Blue Clay . . .	40·6	55·4	12·0	27 73	154	85%
Scarborough	Loam on Clay	40·8	54·1	10·0	26 68	195	83%
Hastings . .	Sand on Sandstone . . .	42·2	57·0	11·8	29 26	187	82%
Eastbourne .	West End Chalk, east Loam	42·2	56·2	11·2	29·53	165	80%
Brighton[1] . .	West End Clay, east Chalk	42·5	57·1	11·2	30·43	163	78%
Southsea . .	Bagshot Sands and Clay .	42·7	55·2	13·8	26·39	173	82%
Ventnor . .	Lower Greensand	44·2	57·7	10·5	28·33	167	80%
Weymouth .	Sand, Shingle, Clay . . .	43·5	56·8	10·3	27·61	162	81%
Teignmouth	Marl, parts Sand	43·8	57·0	12·4	32·28	169	82%
Torquay . . .	Limestone	43·5	55·9	10·8	31·72	177	80%
Falmouth . .	Slate on Quartz	44·9	57·0	9·5	43·49	204	81%
Ilfracombe .	Shales on Sandstone . . .	44·9	57·0	8·4	31·53	191	85%
Llandudno .	Limestone	42·7	55·2	10·1	27·52	175	79%
Guernsey . .		45·5	57·6	9·1	33·28	192	85%

These averages are taken from the record of the Meteorological Society 1882 to 1888 inclusive.

On the geological and orographical characters of a locality, the perviousness, depth and inclination of the strata, and the contour of the surface, depend the relations of the ground water to the site, the evaporation, radiation, exposure to or shelter from cold winds, the prevalence of fogs and even of clouds, storms and rain fall. Some consumptives benefit by a warm and moist, others by a cold and dry air, if calm; sunshine is a *sine quâ non:* and dangerously deceptive as may be a warm sun with a cold east wind, nothing is so deadly as the same without the sun (C. Kingsley's "*grey* north-easter").

[1] Mean of 14 years, 1879–92.

Summary of Chapter XX.

The barometer is a balance, a column of mercury on one side sustaining a column of the atmosphere on the other, the weight of which is indicated by the height to which the mercury rises in the tube above the level of that in the cistern which in the Standard barometer is adjusted to the zero of the scale by means of a moveable bottom.

The weight of the atmosphere at any place and time, depends on its temperature and the amount of aqueous vapour, which is lighter than air, and also on the altitude of the place, each 100 feet of elevation causing a depression of $\frac{1}{10}$ inch, so that the barometer may be used for calculating heights.

All observations are reduced to sea level, and as regards the expansion of the mercury by heat, to $0°C = 32°F$. The scale is marked to $\frac{1}{10}$ or $\frac{1}{20}$ of an inch, smaller fractions being read by a vernier.

Thermometers are used to determine the shade temperature protected from all disturbing influences, and some are made to register the maximum and minimum reached in the twenty-four hours. Another for solar radiation is enclosed in a vacuum tube, and its bulb blackened to aid absorption and accumulation of radiant heat, and a third is fixed near the ground to indicate terrestrial radiation.

Humidity. The air always holds a proportion of (gaseous) aqueous vapour, the possible maximum rising with, but more rapidily than, the temperature. When it holds the maximum for the actual temperature it is said to be saturated, and lesser proportions are described as percentages of saturation or degrees of humidity. The temperature at which the actual amount would become the maximum possible is called the dew point, because if the temperature fall any further the excess will be thrown down as dew.

The dew point and the actual degree of humidity are calculated by tables from a comparison of the readings of the shade thermometer or dry bulb with those of another, the bulb of which is kept wet and exposed to evaporation.

Rain is caused by the meeting of masses of vapour-laden air with other of lower temperature, or with the cold tops of mountains and hills. It is measured by rain gauges.

Winds. The disturbance of equilibrium caused by the unequal densities of masses of air variously warmed by the sun, and affected by evaporation from the ocean, causes movements called Winds, which usually take the form of vortices, centripetal

(cyclones) if the pressure at the centre be the lowest, and centrifugal (anticyclones) if it be the highest: the velocity of the wind depending on the abruptness of the difference between the higher and lower pressures, or the gradient; while this and its circular or spiral direction inwards or outwards determine the distinctive characters of cyclones and anticyclones.

Vanes show the direction of the wind, and anemometers its velocity and pressure.

The conditions of the formation of fogs are not unlike those of rain, but dew is the result of terrestrial radiation and the cooling below its dew point of the air in contact with the earth. It is deposited only when radiation is unchecked by clouds, or other means of shelter, and if the dew point be below freezing, hoar frost is deposited.

Climate is the resultant of temperature, humidity, rainfall, atmospheric pressure, &c. Since the sea absorbs and parts with its heat more slowly than the land, the climates of maritime districts are more equable than those of others remote from its influence, where extremes of heat and cold are reached in summer and winter, and even the diurnal oscillations are greater. Mean temperatures for the whole year give no real information, for as in England and in parts of Northern Asia the mean annual temperature may be 50°, but those of January and July 40° and 60°, or 0° and 80°.

Local climates are greatly influenced by the soil, and to a less extent by the aspect, and configuration and contour of the land, the rainfall, prevailing winds, and of course by the elevation.

QUESTIONS ON CHAPTER XX

1. Explain the movements of the air on the sea border. Of what importance are these movements? 1884,E.

2. Describe the usual method for determining the amount of moisture in the air. How is the amount usually expressed? 1884,A.

3. What influence have (*a*) elevation above the sea, and (*b*) distance from the sea, on the climate of a place? 1885,E.

4. Describe the rain gauge and the method of graduating its measuring glass. If an inch of rain falls in twenty-four hours, how many gallons of water can be collected in that time from a roof 60 feet by 40 feet? 1886,A.

5. What is the average rainfall in England? Mention the chief conditions influencing the rainfall of a place or country? 1892, A.

6. What is the average rainfall of the Eastern and Western districts of Great Britain, and what is the cause of the difference? Where are the heaviest rainfalls, and how do you account for the occurrence of spots where the rainfall is extremely low in the same localities?

7. What is the best position for a rain gauge and why should it never be placed on a wall or parapet?

8. Is there any relation between rainfall and humidity? On what physical conditions does each depend?

9. What is the essential and primary cause of the movements of the air called winds, and what topographical conditions modify these? What is meant by "gradients," and how do they determine the velocity of the wind?

10. What course do winds usually follow? Distinguish between cyclones and anti-cyclones, as regards area, gradient and distribution of barometric pressure, and direction and velocity of the winds. What kind of weather attends each, and what is their influence on the temperature in summer and in winter respectively?

11. What influence has (1) temperature and (2) humidity on the barometric pressure? Why do N., N.E. and E. winds bring a rise of the barometer and dry weather, and W. and S.W. a fall and rain?

12. What is the principle of the barometer, and what does it tell? Why does a high barometer usually bring fine weather, and a fall precede rain?

13. How may the barometer be used to determine the altitude of a place? If it usually stand at 30 inches on the plain what would it read at an elevation of 5,000 feet?

14. Why is it that the ordinary hall barometer is wholly unfit for scientific observations, giving readings always too high or too low save at one degree of pressure? How is this error adjusted in the standard barometer?

15. Describe the aneroid barometer, its principle, its advantages, and its defects.

16. Describe in order and detail the procedure of taking a barometric observation, the adjustment of the scale, the use of the vernier, and the correction of the reading for altitude and temperature.

17. What are *isobars*, and what form [and order] do they usually assume? What conditions of weather are commonly associated with each form? 1895, H.

18. What is meant by "insular" and "continental" climates? What influence does the Gulf Stream exert on the N.W. shores of Europe? Compare the summer and winter temperatures of Bavaria and Iceland.

19. What effect is exerted by aqueous vapour on the radiant heat of the sun? Snow rarely lies in the Shetlands, yet corn will not ripen. Why?

20. Describe the use, indications and position of the "shade," "sun," and "grass" thermometers: explain the peculiar construction of the "sun" thermometer, and of the maximum and minimum self-registering thermometers.

21. What is terrestrial radiation, and by what conditions is it influenced?

22. What is meant by the dew point? Explain the formation of dew, and why it is not deposited on cloudy nights, or beneath trees or awnings.

23. Discuss the formation of the several kinds of fogs. Why are they favoured by the presence of smoke in the air?

24. Under what relations between the afternoon shade temperature and the dew point, may one expect dew or hoar frost at night or not?

25. Discuss the formation of rain and snow.

26. Why is dew or hoar frost heavier after a warm than after a cool day?

APPENDIX.

METRICAL AND BRITISH WEIGHTS AND MEASURES.

THE French Metrical system is based upon the (assumed) length of the fourth part of a terrestrial meridian. The ten-millionth part of this arc was chosen as the unit of measures of length, and called a *Mètre.* The cube of the tenth part of the mètre was adopted as the unit of capacity, and denominated a *Litre.* The weight of a litre of distilled water at its greatest density was called a *Kilogramme*, of which the thousandth part, or *Gramme*, was adopted as the unit of weight. The multiples of these, proceeding in decimal progression, are distinguished by the employment of the prefixes *deca*, *hecto*, *kilo*, and rarely *myria*, from the Greek, and the subdivisions by *deci*, *centi*, and *milli*, from the Latin :—

Measures of Length (*unit Mètre*).

EQUAL TO	Inches.	Feet.	Yards.	Fathms.	Miles.
Millimètre	0·03937 ...	0·003 ...	0·001 ...	0·000 ...	0·000
Centimètre	0·39371 ...	0·032 ...	0·010 ...	0·005 ...	0·000
Décimètre	3·93708 ...	0·328 ...	0·109 ...	0·054 ...	0·000
MÈTRE...............	39·37079 ...	3·280 ...	1·094 ...	0·546 ...	0·000
Décamètre	393·70790 ...	32·808 ...	10·936 ...	5·468 ...	0·006
Hectomètre.........	3937·07900 ...	328·089 ...	109·363 ...	54·681 ...	0·062
Kilomètre...........	39870·79000 ...	3280·899 ...	1093·633 ...	546·816 ...	0·621

Cubic, or Measures of Capacity (*unit Litre*).

EQUAL TO	Cub. In.	Cub. Feet.	Pints.	Gallons.	Bshls.
Millilitre, or cubic centim................	0·06103 ...	0·000 ...	0·001 ...	0·000 ...	0·000
Centilitre, 10 cubic do.	0·61027 ...	0·000 ...	0·017 ...	0·002 ...	0·000
Décilitre, 100 cubic do.	6·10271 ...	0·003 ...	0·176 ...	0·022 ...	0·002
LITRE, or cubic Décimètre................	61·02705 ...	0·035 ...	1·760 ...	0·220 ...	0·027
Décalitre, or Centistère	610·27052 ...	0·353 ...	17·607 ...	2·200 ...	0·275
Hectolitre, or Décistère	6102·70515 ...	8·531 ...	176·077 ...	22·009 ...	2·751
Kilolitre, or Stère......	61027·05152 ...	35·316 ...	1760·773 ...	220·096 ...	27·512

Measures of Weight (*unit Gramme*).

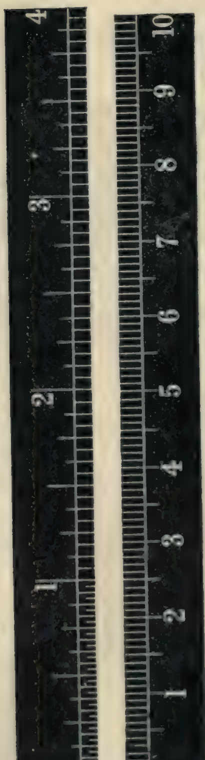


Fig. 39.

Equal to	Grains.	Troy oz.	Avoir. lb.
Milligramme ...	0·01543 ...	0·000 ...	0·000
Centigramme ...	0·15432 ...	0·000 ...	0·000
Décigramme ...	1·54323 ...	0·003 ...	0·002
Gramme	15·43235 ...	0·032 ...	0·002
Décagramme ...	154·32349 ...	0·321 ...	0·020
Hectogramme ...	1543·23488 ...	3·215 ...	0·224
Kilogramme	15432·34880 ...	32·150 ...	2·200

Table for converting Metric Weights and Measures.

Mètres into yards.			Kilomètres into miles and yards.			
1	=	1·094	1	=	[illegible]	1094
2	=	2·187	2	=	1	427
3	=	3·281	3	=	1	1521
4	=	4·374	4	=	[illegible]	855
5	=	5·468	5	=	3	188
6	=	6·562	6	=	3	1282
7	=	7·655	7	=	4	615
8	=	8·749	8	=	4	1709
9	=	9·843	9	=	5	1043
10	=	10·936	10	=	6	376
20	=	21·873	20	=	12	753
30	=	32·809	30	=	18	1129
40	=	43·745	40	=	24	1505
50	=	54·682	50	=	31	122
60	=	65·618	60	=	37	498
70	=	76·554	70	=	43	874
80	=	87·491	80	=	49	1251
90	=	98·427	90	=	55	1627
100	=	109·363	100	=	62	243
200	=	218·727	200	=	124	487
300	=	328·090	300	=	186	730
400	=	437·453	400	=	248	973
500	=	546·816	500	=	310	1217

Litres into gallons and quarts.		
1 =	0	0·880
2 =	0	1·761
3 =	0	2·641
4 =	0	3·521
5 =	1	0·402
6 =	1	1·282
7 =	1	2·163
8 =	1	3·043
9 =	1	3·923
10 =	2	0·804
20 =	4	1·608
30 =	6	2·412
40 =	8	3·215
50 =	11	0·019
60 =	13	0·823
70 =	15	1·627
80 =	17	2·431
90 =	19	3·325
100 =	22	0·039
200 =	44	0·077
300 =	66	0·116
400 =	88	0·155
500 =	110	0·193

Kilogrammes into	cwts.	qrs.	lbs.	oz.
1 =	0	0	2	3¼
2 =	0	0	4	6½
3 =	0	0	6	9¾
4 =	0	0	8	13
5 =	0	0	11	0¼
6 =	0	0	13	3½
7 =	0	0	15	7
8 =	0	0	17	10¼
9 =	0	0	19	13½
10 =	0	0	22	0¾
20 =	0	1	16	1½
30 =	0	2	10	2½
40 =	0	3	4	3
50 =	0	3	26	3¾
60 =	1	0	20	4½
70 =	1	1	14	5¼
80 =	1	2	8	6
90 =	1	3	2	6½
100 =	1	3	24	7
200 =	3	3	20	15
300 =	5	3	17	6
400 =	7	3	13	14
500 =	9	3	10	5

To convert kilogrammes into tons × 0·0009.

To convert tons into kilogrammes × 1011·8.

STANDARD SOLUTIONS AND REAGENTS.

Water, distilled and ammonia free.

Nessler's Sol.—Dissolve 62·5 grm. KI in 250 c.c. water, set aside 1 c.c. Dissolve 35 grm. Hg,Cl^2 in 600 c.c. warm water, and when cold add it gradually to the former till slight precipitate appears, dissolve this by dropping in some of the reserved 1 c.c. of KI sol. Then add 150 grm. of KHO in 150 c.c. of water, and make up with water to 1 liter.

Alkaline Permang. Sol.—Dissolve 8 grm. pot. permang. and 200 grm. KHO in 1100 c.c. water, boil to 1000 c.c., or till distillate is free from ammonia, and if necessary make up to 1000 c.c.

Standard Ammonia Sol.—Dissolve 3·15 grm. $(NH^4)Cl$ in liter of water for strong stock sol. For standard pipette 5 c.c. of this into 495 c.c. of water.

Standard Silver Sol.—Dissolve 4·788 grm. $AgNO^3$ in 1000 c.c. water. 1 c.c. = ·001 gr. Cl. ∴ with 100 c.c. of water it represents 1 pt. per 100,000. *Indicator*, 1 pt. of pot. chromate in 10 of water.

Phenol Sulphuric Acid.—Digest for several hours at 100° C. 6 grm. pure phenol and 3 c.c. of water in 37 c.c. of H^2SO^4.

Liq. Potassæ.—A 50 per cent. sol. of pure KHO.

Standard Nitrate Sol.—Dissolve 0·722 grm. of recently fused KNO^3 in 1000 c.c. of water. 10 c.c. = ·001 grm. N.

For Estimation of Absorbed Oxygen.

1. *Pot. Permang. Sol* —0·395 grm. in 1000 water, 10 c.c. = ·001 grm. oxygen.
2. *Sod. thio-sulphate Sol.*—1 grm. in liter.
3. *Dilute Sulphuric Acid.*—100 c.c. in 300 c.c. water.
4. *Potassium Iodide.*—10 per cent. solution.
5. *Starch Solution.*—1 grm. of rice starch worked to a cream with cold water added to 100 c.c. of boiling water, and boiled for ten minutes. When cold decant off the clear liquid. It must be freshly prepared.

Griess's Test for Nitrites.

Solution 1. Metaphenylene diamine 5 grms. in a liter, acidulated with H^2SO^4.

Solution 2. Sulphuric acid solution 35 per cent.

Solution 3. Standard nitrite solution, potassic nitrite = 00·1 mg. N^2O^3 in each cc.

[Argentic nitrite ·406 grm. dissolved in 100 ccs. hot water, decomposed by slight excess of KCl, and the clear solution decanted off the ppt. of AgCl. and diluted with distilled water to 1000 ccs.]

Standard Soap Sol. is best bought ready made of manufacturing chemists, when a table will be found attached, showing the number of parts per 100,000, and "degrees" of Clark's scale, or parts per 70,000, indicated by each c.c. and tenths of a c.c. required by 50 c.c. of the water, corrected by the deduction of 0·7 c.c. used up in the formation of a permanent lather after the removal of the earthy salts.

A few Chemical Values for ready reference.

Atomic Weights and Valencies.

II.	Barium ...	Ba	137
II.	Calcium ...	Ca	40
II.	Carbon ...	C	12
I.	Chlorine ...	Cl	35·5
II.—IV.	Chromium ...	Cr	52·2
I.	Hydrogen ...	H	1
I.	Iodine ...	I	127
II.—IV.	Iron	Fe	56
II.	Lead	Pb	207
II.	Magnesium ...	Mg	24
II.	Manganese ...	Mn	55
II.	Mercury ...	Hg	200
III.—V.	Nitrogen ...	N	14
II.	Oxygen ...	O	16
III.—V.	Phosphorus ...	P	31
I.	Potassium ...	K	39·1
I.	Silver... ...	Ag	108
I.	Sodium ...	Na	23
II.	Sulphur ...	S	32
	Double atoms.		
VI.	Chromium ...	Cr^2	104·4
VI.	Iron	Fe^2	112
II.	Mercury ...	Hg^2	400

Molecular Weights of some Compounds.

Ammonia	NH^3	17
Ammonium oxalate	$(NH^4)^2C^2O^4$	124
Barium oxide	BaO	153
,, hydrate	BaH^2O^2	171
,, chloride	$BaCl^2$	208
,, nitrate	$Ba(NO^3)^2$	261
,, oxalate	BaC^2O^4	225
Calcium oxide	CaO	56
,, hydrate	CaH^2O^2	74
,, carbonate	$CaCO^3$	100
,, oxalate	CaC^2O^4	128
Carbon dioxide	CO^2	44
Hydric chloride	HCl	36·5
,, nitrate	HNO^3	63
,, oxalate	$H^2C^2O^4$	90
,, sulphate	H^2SO^4	98
Potassium oxide	K^2O	94·2
,, hydrate	KHO	56·1
,, permanganate ...	$KMnO^4$	158·1
Bipotassium platinic chloride	K^2PtCl^4	448·7
Silver nitrate	$AgNO^3$	170
,, chloride	$AgCl$	143·5
Sodium chloride	$NaCl$	58·5
,, hydrate	$NaHO$	40

Analytical equivalents for estimation of

Chlorine. $AgNO^3 : Cl : NaCl : : 170 : 35·5 : 58·5$.

Lime. $\begin{cases} H^2C^2O^4 : CaH^2O^2 : CaO : : 90 : 74 : 56. \\ (NH^4)^2C^2O^4 : CaH^2O^2 : CaO : : 124 : 74 : 56. \end{cases}$

Sulphates. $\begin{cases} BaCl^2 : H^2SO^4 : : 208 : 98. \\ Ba(NO^3)^2 : H^2SO^4 : : 261 : 98. \end{cases}$

Nitrates. $NH^3 : HNO^3 : : 17 : 63$.

Nitrogen as Nitrates. $N : HNO^3 : : 14 : 63$, or $2 : 9$.

Carbonic dioxide. BaO or $CaO : CO^2 : : 153$ or $56 : 44$.

Lead. $PbS : Pb : : 239 : 207$.
Iron. $FeS : Fe : : 88 : 56$.
Copper. $CuS : Cu : : 95·5 : 63·5$.
} But more easily by colorimetry.

Magnesium. $Mg^2P^2O^7 : Mg^2 : : 222 : 48$.
Potassium. $PtK^2Cl^6 : K^2 : : 488·7 : 78·2$.
} The triple phosphate being reduced by ignition to pyrophosphate.

Ammonia in $(NH^4)^2SO^4$ as $17 : 132$.
Lead in $PbO^2(C^2H^3O)^2$ as $207 : 325$.

ANALYTICAL TABLES OF THE MORE IMPORTANT ARTICLES OF FOOD.

ANIMAL FOODS.

	Water	Albumin.	Fat.	Carbo-hydrates.	Salts.
Beef, best steaks	74·4	20·5	3·50	...	1·6
,, good prime joints (König)	72·25	21·39	5·19		
,, lean (do.)	76·61	20·61	1·50		
,, fattened prize animals (Lawes and Gilbert)	63·00	14·00	19·00	...	3·7
,, Salt (Girardin)	49·10	29·6	0·20	...	21·1
Veal, lean (König)	78·82	19·76	0·82		
,, fat (do.)	72·31	18·88	7·41		
,, fat breast (do.)	64·66	18·81	16·05		
Mutton, good (do.)	75·99	18·11	5·77		
,, very fat (do.)	47·91	14·80	36·39		
,, neck (do.)	41·39	15·45	42·07		
,, shoulder (do.)	60·38	14·57	23·62		
Pork, fat (Letheby)	39·00	9·80	48·9	...	2·3
,, fat (König)	47·40	15·98	34·62		
Bacon (Letheby)	15·00	8·80	73·30	...	2·9
Ham, fat (König)	48·71	15·98	34·62		
,, lean (do.)	69·60	20·97	8·29		
Salt pork (Girardin)	44·10	26·10	7·00	...	22·8
Venison (Von Bilra)	74·63	19·24	1·30		
Hare (König and Farwick)	74·16	23·34	1·07		
Partridge (König)	71·96	25·26	1·43		
Poultry, fatted hen (König)	70·06	18·49	9·34		
,, fat cockerill chick (do.)	70·03	23·32	3·15		
Goose, fat (do.)	38·02	15·91	45·59		
Salmon (do.)	74·36	15·01	6·42		
Eel (do.)	57·42	12·82	28·37		
Herring, fresh (do.)	80·71	10·11	7·11		
Sole (do.)	86·14	11·94	0·25		
Milk (König)	87·41	3·01 cas. 0·75 alb.	3·66	4·92	·70
,, average (Blyth)	86·87	3·98 cas. 0·77 alb.	3·50	4·19	·70
,, country (Wanklyn)	87·55	4·00	3·00	4·60	·70
,, town (do.)	85·93	5·01	4·00	4·30	·70
Cream, raw, mean of five (Bell)	60·75	3·46	32·77	2·41	·53
,, thick (do.)	37·62	1·83	58·77	1·46	·32
,, Devonshire (do.)	33·76	4·97	59·79	1·01	·47
Condensed Milk, Swiss (do.)	26·70	10·20	9·76	51·02	2·32
,, ,, unsweetened (do.)	61·87	11·38	11·26	13·35	2·22
Asses' milk (do.)	91·17	1·09 cas. ·70 alb.	1·02	5·60	·42
Goats' milk (do.)	87·54	3·00 cas. ·62 alb.	4·20	4·08	·56

ANIMAL FOODS—*continued.*

	Water	Albumin.	Fat.	Carbo-hydrates.	Salts.
Butter, best English (Bell)	7·55	1·15	90·27	...	1·03
,, slightly salted, English (do.)	11·71	·95	83·74	...	3·60
,, ,, ,, (Devon)(do.)	16·28	1·56	78·84	...	3·32
,, fresh, English (do.)	12·05	1·95	85·04	...	·96
,, ,, Dorset (do.)	14·62	1·88	82·02	...	1·48
,, highly salted (do.)	13·59	1·36	69·97	...	15·08
,, good German fresh (König)	11·70	·5	87·0	·5	·5
				Extractives.	
Cheese, rich (do.)	35·75	27·16	30·43	2·53	4·13
,, medium (do.)	46·82	27·62	20·54	2·97	3·05
,, poor (do.)	48·02	32·65	8·41	6·80	4·12
				Free acid as lactic.	
,, Stilton (Bell)	23·57	32·55	39·13	1·24	3·51
,, Roquefort and Gorgonzola, mean (do.)	32	27·5	34·3	1·3	4·7
,, Cheddar (do.)	35·60	28·16	31·57	·45	4·22
,, Cheshire (do.)	37·11	26·93	30·68	·86	4·42
,, Dutch (do.)	41·30	28·25	22·78	·37	7·10
Eggs (Parkes)	73·50	13·50	11·60	...	1·00
,, white (König)	85·75	12·67	0·25	...	·59
,, yolk (do.)	50·82	16·24	31·75	...	1·09

Dr. Pollens gives the extremes and means of the composition of condensed milks, sweetened and unsweetened, thus :—

	Water	Albumin.	Fat.	Carbo-hydrates.	Salts.
Sweetened	12·43 25·69 35·66	7·79 12·32 20·14	7·54 10·98 18·78	10·82 16·29 18·35	1·56 2·34 3·87
,, cane sugar added	...	...	...	24·11 32·37 40·48	
Unsweetened (mean)	46-53	13-26	13-20	12½-18	2-3

The difference between the first and last drawn milk of the same cow referred to on page 105 is well shown in the following analyses by Mr. Wynter Blyth :—

	Water	Albumin.	Fat.	Carbo-hydrates.	Salts.
Cows' milk, Devon, fore milk (Blyth)	90·32	{ 2·38 cas. 1·83 alb. }	1·16	3·50	·79
„ „ stripping (do.)	83·94	{ 4·30 cas. ·97 alb. }	5·81	4·07	·89
„ Guernsey, fore milk (do)	88·40	{ 4·70 cas. ·45 alb. }	·35	5·21	·87
„ „ stripping (do)	83·39	{ 3·43 cas. ·86 alb. }	5·94	5·43	·93

VEGETABLE FOODS.

	Water	Albumin.	Fat.	Carbo-hydrates.	Salts.
Wheat, fine, usually sold (Wanklyn)	16·50	13·00	1·50	68·3	·7
„ best household (do.)	12·67	12·09	1·22	72·39	·73
„ best whites (do.)	12·96	13·60	1·08	71·78	·58
„ finest white (König)	14·86	8·91	1·11	74·61	·51
Oatmeal, Scotch (Letheby)	15·00	12·60	5·60	63·00	3·00
„ groats (König)	10·07	14·29	5·65	67·97	2·02
Maize (Pozziale)	13·5	10·00	6·70	64·5	2·4
„ (König)	10·60	14·00	3·80	70·68	·86
Rice (Parkes)	10·00	5·00	·08	83·20	·50
„ flour (König)	14·15	7·43	·89	77·12	·50
Bread, best wheaten (Wanklyn)	34·00	9·50	...	54·50	2·00
„ average (Parkes)	40·00	8·00	1·50	49·20	1·30
„ best German (König)	38·51	6·82	·77	52·72	1·18
„ rye (do.)	44·02	6·02	·48	48·17	1·32
„ Pumpernickel (do.)	43·42	7·59	1·52	45·06	1·42
Biscuit, as supplied to ships and troops	8·00	15·60	1·30	73·40	1·70
Peas (König)	14·31	22·63	1·72	58·79	2·65
Beans, garden (do.)	13·60	23·12	2·28	57·47	3·53
Lentils (do.)	12·51	24·81	1·85	58·36	2·47
Potatoes (Parkes)	74·00	1·50	·19	23·40	1·00
„ (König)	75·77	1·79	·16	21·31	·97
Carrots (do.)	88·32	1·04	·21	10·74	·94
Turnips (do.)	91·24	·96	·16	6·81	·75
Beetroot (do.)	87·07	1·37	·03	10·61	·92
Parsnips (Parkes)	82·04	1·21	·546	14·41	1·04
Cabbage, white	89·97	1·89	·20	4·71	1·23
„ winter	80·03	3·99	·90	13·51	1·57
„ Brussels sprouts	85·63	4·83	·46	7·79	1·29
Cauliflower	90·39	2·53	·38	5·88	·82
Spinach	90·26	3·15	·54	4·11	1·94
French beans	88·36	2·77	·14	9·16	·57
Green peas	80·49	5·75	·50	12·46	·80
Onions	85·99	1·68	·10	11·53	·70
Cucumber and melons	95·40	1·04	...	2·70	·5

FRUITS.

	Water	Nitrogenous matter.	Free acid.	Sugar.	Other Carbo-hydrates	Cellulose and Seeds, &c.	Ash.
Apple	83·58	·39	·84	7·73	5·17	1·98	·31
Pear	83·03	·36	·20	8·26	3·54	4·30	·31
Plum	84·86	·40	1·50	3·56	4·68	4·34	66
Greengage	80·28	·41	·91	3·16	11·46	3·39	·39
Peach, &c.	80·62	·57	1·04	4·59	6·76	5·66	·75
Grapes	78·17	·59	·79	24·36	1·96	3·60	·53
Oranges (without skins or seeds) .	89·01	·73	2·44	4·59	·95	1·79	·63
Cherries	80·26	·62	·91	10·24	1·17	6·07	·73
Strawberry	87·66	1·07	·93	6·28	·48	2·32	·81
Raspberry	86·21	·53	1·38	3·95	1·54	5·90	·49
Gooseberry	85·74	·47	1·42	7·03	1·40	3·52	·42
Currants	84·77	·51	2·15	6·38	·90	4·57	·72
Dried Apples . . .	27·95	1·28	·82	3·60	42·83	4·95	1·57
,, Pears	29·41	2·07	·35	·84	29·13	6·86	1·67
,, Raisins . . .	32·02	2·42	·59	...	54·56	1·72	1·21
,, Figs	31·20	4·01	1·44	1·21	49·79	4·98	2·86
				Fat.	Carbo-hydrates		
Sweet Almond . .	5·39	24·18	...	53·68	7·23	6·56	2·96
Walnut	4·68	16·37	...	62·86	7·86	6·17	2·03
Hazelnut	3·77	15·62	...	66·47	9·03	3·28	1·83
Chestnuts, fresh . .	51·48	5·48	...	1·37	38·34	1·61	1·72

THE CENSUS (1901), ENGLAND AND WALES.

POPULATION ENUMERATED IN 1891 AND 1901.

	Population. 1891.	Population. 1901.
ENGLAND AND WALES	29,002,525	32,525,716
62 Administrative Counties	20,935,597	23,386,526
67 County Boroughs	8,066,928	9,139,190
ADMINISTRATIVE COUNTIES.		
ENGLAND—		
Bedfordshire	161,378	171,699
Berkshire	176,119	180,366
Buckinghamshire	186,680	196,843
Cambridgeshire	120,645	120,634
Isle of Ely	63,340	64,494
Chester	535,944	601,042
Cornwall	322,571	322,857
Cumberland	266,549	266,904
Derbyshire	425,472	504,577
Devonshire	442,287	436,913
Dorset	193,542	202,093
Durham	720,793	833,310
Essex	578,471	816,524
Gloucestershire	323,980	331,515
Herefordshire	115,762	114,150
Hertfordshire	226,587	258,044
Huntingdonshire	55,015	54,127
Kent	807,328	936,003
Lancaster	1,564,696	1,827,330
Leicestershire	201,639	225,895
Lincolnshire—Holland	76,204	77,583
,, Kesteven	105,361	103,957
,, Lindsey	199,051	206,497
London	4,228,317	4,536,034
Middlesex	542,894	792,225
Monmouthshire	203,426	230,792
Norfolk	318,301	313,438
Northamptonshire	189,218	207,466
Soke of Peterborough	35,249	41,119
ENGLAND—*continued.*		
Northumberland	319,730	387,728
Nottinghamshire	231,745	274,683
Oxfordshire	143,753	137,118
Rutlandshire	20,659	19,708
Shropshire	236,827	239,297
Somerset	378,166	385,059
Southampton	334,194	377,121
Isle of Wight	78,672	82,387
Staffordshire	771,258	879,625
Suffolk—Eastern	183,405	189,153
,, Western	121,350	117,535
Surrey	419,115	519,522
Sussex—Eastern	227,699	261,691
,, Western	140,987	151,540
Warwickshire	301,412	347,693
Westmoreland	66,215	64,411
Wiltshire	262,551	271,372
Worcestershire	297,389	358,357
Yorkshire—East Riding	141,180	145,877
,, North Riding	284,015	285,681
,, West Riding	1,294,423	1,460,857
WALES—		
Anglesey	50,098	50,475
Brecknock	51,393	54,211
Cardigan	63,467	61,068
Carmarthen	130,566	135,320
Carnarvon	117,586	125,654
Denbigh	118,979	131,588
Flint	77,041	81,487
Glamorgan	467,954	601,080
Merioneth	48,859	48,786
Montgomery	58,003	54,892
Pembroke	88,296	87,856
Radnor	21,791	23,263

Population Enumerated in 1891 and 1901 in County Boroughs.

County Boroughs.	Population. 1891.	Population. 1901.	County Boroughs.	Population. 1891.	Population. 1901.
Barrow-in-Furness.	51,712	57,589	Leicester	174,624	211,574
Bath	51,844	49,817	Lincoln	41,491	48,783
Birkenhead	99,857	110,906	Liverpool	629,548	685,276
Birmingham	478,113	522,182	Manchester	505,368	543,930
Blackburn	120,064	127,527	Middlesborough	75,532	91,300
Bolton	146,487	168,205	Newcastle-on-Tyne	186,300	214,881
Bootle	49,217	57,913	Newport (Monmth.)	54,707	61,474
Bournemouth	37,785	47,003	Northampton	75,075	87,021
Bradford	265,728	279,809	Norwich	100,970	111,728
Brighton	115,873	123,478	Nottingham	213,877	239,753
Bristol	289,280	328,836	Oldham	131,463	137,238
Burnley	87,016	97,044	Oxford	45,742	49,413
Burton-on-Trent	46,047	50,386	Plymouth	88,926	107,509
Bury	57,212	58,028	Portsmouth	159,278	189,160
Canterbury	23,062	24,401	Preston	107,573	120,860
Cardiff	128,915	163,844	Reading	60,054	72,214
Chester	37,105	36,281	Rochdale	76,161	83,112
Coventry	58,503	69,877	St. Helens	72,413	84,410
Croydon	102,695	133,885	Salford	198,139	221,015
Derby	94,146	105,785	Sheffield	324,243	380,717
Devonport	55,981	69,674	Southampton	82,126	103,500
Dudley	45,724	48,809	South Shields	78,391	97,272
Exeter	45,588	47,180	Stockport	70,263	78,871
Gateshead	85,692	109,891	Sunderland	131,686	146,828
Gloucester	41,303	47,944	Swansea	90,349	94,505
Great Yarmouth	49,334	51,250	Walsall	71,789	86,440
Grimsby	51,934	63,119	Warrington	55,238	64,241
Halifax	97,714	104,997	West Bromwich	59,538	65,172
Hanley	54,946	61,519	West Ham	204,903	267,308
Hastings	63,072	65,528	Wigan	55,013	60,770
Huddersfield	95,420	95,008	Wolverhampton	82,662	94,179
Ipswich	57,433	66,622	Worcester	42,908	46,620
Kingston-on-Hull	200,472	238,562	York	67,749	77,790
Leeds	367,505	428,953			

London and the Outer Ring.

The following table shows the population of Inner and Outer London and the totals for Greater London, as brought out by the censuses of 1871, 1881, 1891, and 1901.

	1871.	1881.	1891.	1901 (Provisional).
Inner London	3,253,785	3,815,544	4,211,743	4,536,034
Outer Ring	631,856	951,117	1,422,063	2,042,750
Greater London	3,885,641	4,766,661	5,633,806	6,578,784

ERRORS IN THE ESTIMATED POPULATION OF THE 33 GREAT TOWNS SHOWN BY THE CENSUS 1901.

Liverpool . . .	−7·8	Manchester . .	+1·8	Leicester . . .	+ 5·8
Wolverhampton	−4·2	Halifax	+1·8	Preston	+ 6·1
Plymouth . . .	−3·7	Leeds	+2·2	Birkenhead . .	+ 7·0
Sheffield . . .	−2·7	Hull	+2·2	Huddersfield .	+ 9·9
Bristol	+0·1	Gateshead . .	+2·2	Newcastle . .	+10·5
Birmingham .	+0·4	London	+2·5	Oldham . . .	+11·9
Croydon . . .	+0·6	Nottingham .	+2·6	Swansea . . .	+11·9
Salford	+1·1	Derby	+3·5	Blackburn . .	+15·5
Bolton	+1·2	Norwich . . .	+4·1	Cardiff	+18·8
Brighton . . .	+1·3	Bradford . . .	+5·0	West Ham . .	+18·9
Sunderland . .	+1·6	Portsmouth . .	+5·1	Burnley . . .	+19·5

Errors not exceeding + or − 5% may be deemed unavoidable and might occur in a quinquennial census, but in eight of the 33 towns the population has been over-estimated by 10% or more, and in three of these by nearly 20%, completely falsifying the death-rates, *e.g*, Burnley's assumed death-rate of 19·6 proves to be no less than 22·8.

The case of Liverpool is specially instructive. Over-estimated in 1891, when commercial depression had checked the stream of immigration and turned the increase in the decennium 1871-81 of 12% into a decrease of 6·2% in the period 1881–91, it has now been under-estimated by 7·8% in consequence of a turn of the tide, but though the death-rate will be lowered by the correction, it remains to be seen whether there is any *natural increase* of the population, or whether the deaths still exceed the births.

CENSUS (1901), SCOTLAND.

Counties.	Population.	Increase.	Decrease.
Aberdeen	303,889	19,853	—
Argyll	73,166	—	919
Ayr	254,133	27,747	—
Banff	61,439	—	245
Berwick	30,785	—	1,505
Bute	18,659	255	—
Caithness	33,619	—	3,558
Clackmannan	31,991	—	1,149
Dumbarton	113,660	15,646	—
Dumfries	72,562	317	—
Edinburgh	437,553	3,277	—
Elgin	44,757	1,286	—
Fife	218,350	27,985	—
Forfar	283,729	5,994	—
Haddington	38,653	1,276	—
Inverness	89,901	—	220
Kincardine	40,891	5,399	—
Kinross	6,980	307	—
Kirkcudbright	39,359	—	626
Lanark	1,337,848	231,949	—
Linlithgow	64,787	11,979	—
Nairn	9,291	136	—
Orkney	27,723	—	2,730
Peebles	15,066	316	—
Perth	123,255	1,070	—
Renfrew	268,416	37,606	—
Ross and Cromarty	76,149	—	2,578
Roxburgh	48,793	—	4,707
Selkirk	23,339	—	4,373
Shetland	27,755	—	956
Stirling	141,894	23,873	—
Sutherland	21,389	—	507
Wigtown	32,591	—	3,471
Afloat in Scottish Waters	9,583	—	—
Total	4,471,957	438,854 { Net increase	

TOWNS WITH POPULATIONS OF OVER 50,000.

	Population.	Increase.		Population.	Increase.
Glasgow	760,423	142,371	Leith	76,667	6,782
Edinburgh	316,479	51,683	Govan	76,351	27,987
Aberdeen	153,108	29,781	Greenock	67,645	4,133
Dundee	100,871	5,196	Partick	54,274	17,736
Paisley	79,355	2,471			

POPULATION OF IRELAND IN 1901.

LEINSTER	1,150,485	ULSTER	1,581,357
Carlow	37,723	*Antrim	461,240
*Dublin	447,266	Armagh	125,238
Kildare	63,469	Cavan	97,368
Kilkenny	78,821	Donegal	173,256
King's	60,129	*Down	289,335
Longford	46,581	Fermanagh . . .	65,243
Louth	65,741	*Londonderry . . .	144,329
Meath	67,463	Monaghan	74,505
Queen's	57,220	Tyrone	150,468
Westmeath . . .	61,527		
Wexford	103,860		
Wicklow	60,679	MUNSTER	1,075,075
CONNAUGHT . .	649,635	Clare	112,129
		*Cork	404,813
Galway	192,146	Kerry	165,331
Leitrim	69,201	*Limerick	146,018
Mayo	202,627	Tipperary	159,754
Roscommon . . .	101,639	*Waterford	87,030
Sligo	84,022		

* The populations of these counties include those of the County Boroughs.

POPULATIONS OF THE LARGER TOWNS IN IRELAND.

Dublin	289,108	These are the populations of the *municipal* boroughs; the areas of those of Belfast and Waterford having been enlarged since 1891.
Belfast	348,965	
Cork	75,978	
Limerick	38,085	
Londonderry	39,873	
Waterford	26,743	

Two urban districts within the County of Dublin have populations over 25,000.

Rathmines and Rathgar	32,472
Pembroke	25,524

The decrease of the population which has taken place since the census of 1891 amounts to 5·3% for the whole country, and in all the counties (except Dublin, Down and Antrim, which have increased 7·0 to 7·3%) there has been a decrease of from 5·1 to 13·6%.

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THE END

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